ELECTRIC STATIONS

By

Prof. Dr. Mohamed Hamed

Faculty of Engineering
Port Said - Egypt

hamed639@hotmail.com

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مع ملاحظة أن البيانات الخاصة برقم التصنيف ورؤوس الموضوعات سوف تكون من مسئولية الشئون الفنية بدار الكتب المصرية

ملحوظة: هذه البيانات لا تنطبق إلا على العنوان ولا تعمم في عناوين أخرى.

بيان تفصيلي بالشكل العام لمحتوى الكتاب

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Author: Prof. Dr. Mohamed Hamed

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Abstract:

This book presents the basics and requirements for the design of an electric station. It studies the design basics and indicates the types of stations in a network. It explains the target as a descriptive engineering view more than the mathematical analysis. It also, simplifies the hard content of a design element as it begins with the bus bar styles in a station. Illustration using both drawings and pictures together has considered a base for simplification in order to aid the reader to understand the three dimension (space coordinates) wiring in a station. The roll of reactive power in a network has been inserted in the book and then the use of reactive elements in a station with reasons. Elements of a station have been explained in details from the point of designer view. The towers were classified and explained as well as the elements of current breaking are studied for applications in a station. Measuring principle in stations is shown with the required styles for recording and protection or control. Elements and components of auxiliaries in stations are studied in details while the single line diagram is analyzed for the design purpose. After that, the lay out of a station has been analyzed from the beginning till the designer level where two chapters are opened for illustration. A mathematical concept is considered to help engineers when necessary. Also, the switching transients are presented for the exact design at the good insulation level. This has been given as a statistical study for the transients and so, Statistical Profile can be deduced for a transmission line (connectors between stations). The book deals with the renewal energy stations as well as their coupling with the united network. The costing and pricing of energy is shortly derived where an example for Egyptian pricing is considered with a real sample. A correlation factor is recommended for a good evaluation. The effect of power loss has been inserted in order to reduce the costing of energy. The work depends on 143 References listed at the end of book. This book is suitable for students in faculties of engineering and high engineering institutes. It is a good reference for engineering and especially for designers. It can be useful for the post graduate students as a course and for researchers although it is a simple form of books. This simplicity helps the students of technical schools and institutes to understand. It is a valuable material for the training programs of engineers where it is recommended for all students and technician as well engineers.

موجز

يقدم الكتاب الحالي موضوعا هاما وحيويا لمهندسي الكهرباء المتخصصين في المحطات والشبكات الكهربية بكافة مستوياتها وجهودها، كما أنه يقدم مبادئ التصميم لهذه المواقع في صورة مبسطة وسهلة الفهم، وهو يعد مرجعا جيدا لمهندسي تصميم المحطات وشبكات التوزيع والنقل الكهربية علي حد سواء. يتحاور الكتاب ذاتيا مع عناصر داخلية وخارجية لمكونات هذه المحطات حيث أفرد صفحات عديدة لهذه العناصر وقدم تفصيلا سريعا لأنواع المحطات، وقد وضع المكونات الرئيسية وتلك المساعدة داخل هذه المحطات في إطار عام وقد نوعها أيضا تبعا لأنواعها الخدمية. تم شرح كيفية وضع الرسم الخطي للمحطة وكيفية التعامل معه ثم التوصل إلي أسلوب توزيع المكونات الداخلية كل علي حدة ثم في مجموعة خلية واحدة، كما وضع أسس التعامل مع المساقط الهندسية لشكل المحطة أو لمقاطع الخلايا بها وكيفية التوصل إلي الحلول الإقتصادية ووسائل توفير مساحة الأرض اللازمة لإنشاء محطة ما. تعرض الكتاب لجميع نوعيات الأبراج الكهربية المستخدمة في خطوط النقل الكهربي وكيفية التعامل معها هندسيا للحصول علي أفضل استخدام وصيانة من أجل التصميم الكهربي الجيد لعناصر الشبكات بشكل عام. تم تخصيص فصلا كاملا عن الطاقة الجديدة والمتجددة بالإضافة إلي فصل آخر عن تسعير الكهرباء وخاصة في جمهورية مصر العربية والمقترحات الخاصة بتصحيح أسعار بيع الكهرباء وتطرق في فصل موسع لنقاط تحديد مستوي العزل للشبكات الكهربية تبعا للدراسات الإحصائية البحثية لجهود الفجائيات الداخلية في شبكات الجهد العالي والجهد الكهربي الفائق.

يعتبر هذا الكتاب مرجعا أساسيا لمهندسي الكهرباء لأنه يحتوي علي المادة العلمية لبرامج تدريب المهندسين من أجل التنمية البشرية المتخصصة في مجال الشبكات الكهربية، ويتميز بالسهولة في الشرح لدرجة أنه قد يصلح لطلاب كليات الهندسة والمعاهد الهندسية المختلفة بمرحلة البكالوريوس، علاوة علي أنه يساعد الباحثين وطلاب الدراسات العليا في ذات المجال، كما أنه مبسط لأنه يعتمد علي الشرح بالرسم والصور الفوتوغرافية ومقدم باللغة الإنجليزية.

Introduction

Energy is a modern problem on the glob because the advancement of technology is spread around the world. So, a good treatment for the subject of energy may help well in the standard of living of the people. Thus, it may be an interested item to be proposed for study. On the other hand, energy comes from a raw material of a fuel which can be an input energy for a station. Then, this station gives us this energy to be easy for utilization because it must serve the human in its life.

It is seen that the electric power is the known shape of energy required for people because of the spread electric energy as a common use, recently. This electric energy may be generated from other shapes of energy according to energy conversion.

Therefore, electric energy generation and utilization would be the way for a good management for this energy. Then, all types of electric stations could be a target for investigation. Also, the tendency to manage such a subject may be an interesting title for engineers as well as for students in the same field.

The given book relates to the construction as well as the details of content in electric stations in general. Therefore, the design process including the basics of the systems in the field besides others may be a target to reach. The book talks to engineers and students inside the electrical Power Engineering and helps to a great extent the designers to act better.

The book contains all details required for the subject of design an electric station while it presents most of the related items such as the connections between station in a national network as well as components inside a station. It also, classifies the electric stations and consequently, describes some of them. The strategy of this book is the descriptive engineering view for the subject as a meaning and reality although it takes the simplification concept for study. It is important to treat the subject of a design in details in order to find the best of the best solutions we can find. Therefore, the problem of the design of electric stations can be considered as one of the vital engineering sections so that it may be in the circle of our interest.

This book presents the basics and requirements for the design of an electric station. It studies the design basics and indicates the types of stations in a network. It explains the target as a descriptive engineering view more than the mathematical analysis. It also, simplifies the hard content of a design element as it begins with the bus bar styles in a station. Illustration using both drawings and pictures together has considered a base for simplification in order to aid the reader to understand the three dimension (space coordinates) wiring in a station.

The proposed current book consists of 14 chapters in addition to a reference list and an introduction. Its language appears to be very simple in order that the new students in the field can understand. Whatever, the title of the book is a general one but the work done is so directed towards the design of stations.

This means that the theoretical analysis driven here is a basic type where elementary mathematics may be necessary. Although the design problem is a high level of interest, the simplicity of the material in this book helps well all readers, even students of technical schools.

The roll of reactive power in a network has been inserted in the book and then the use of reactive elements in a station with reasons. Elements of a station have been explained in details from the point of designer view. The towers were classified and explained as well as the elements of current breaking are studied for applications in a station.

Measuring principle in stations is shown with the required styles for recording and protection or control. Elements and components of auxiliaries in stations are studied in details while the single line diagram is analyzed for the design purpose. After that, the lay out of a station has been analyzed from the beginning till the designer level where two chapters are opened for illustration.

A mathematical concept is considered to help engineers when necessary. Also, the switching transients are presented for the exact design at the good insulation level. This has been given as a statistical study for the transients and so, Statistical Profile can be deduced for a transmission line (connectors between stations). The book deals with the renewal energy stations as well as their coupling with the united network.

The costing and pricing of energy is shortly derived where an example for Egyptian pricing is considered with a real sample. A correlation factor is recommended for a good evaluation. The effect of power loss has been inserted in order to reduce the costing of energy. The work depends on 143 References listed at the end of book.

The most important data had been tabulated though out the chapters where the actual design works depends on the tabulation system. Whatever, the target of this book is the logic understanding for the engineering design technology so that the simple view without the usual complex equations and the hard mathematical formulation. This leads to the advantage of the simplicity for such problems.

This book is suitable for students in faculties of engineering and high engineering institutes. It is a good reference for engineering and especially for designers. It can be useful for the post graduate students as a course and for researchers although it is a simple form of books. This simplicity helps the students of technical schools and institutes to understand. It is a valuable material for the training programs of engineers where it is recommended for all students and technician as well engineers.

Finally, the subjects studied here are integrated to cover the problem as a whole while each chapter is an independent flag.

Author
hamed639@hotmail.com

Chapter I

BASICS

Electric networks represent one of the most important engineering networks such as water supply networks and road networks or gas and black oil systems as well as communication and information networks. These may be local or international systems either in the form of radial or interconnected style. In the field of design for such systems, there are some important Basic Rules that must be taken into account first although different solutions can be reached in various concepts. This makes the rules as a basic title more important and consequently, these basic rules may simplify the complicated problem. Thus the main items in the field can be easily explained so that the new engineers could treat and discuss such subjects. This needs a complete information about some items as tailored next.

1 - 1: OBJECTIVE FUNCTION

The requirements that must be realized in the final solution of the design appear to be the first goal of understanding. All presented materials could be helpful for the reader in order to take an action as a designer. The fundamental conditions for a good design may be shortly indicated below.

1- Simplicity

The simplicity might be presented in all elements individually or in the final result including the connection, installation, maintenance and operations. The strategy of simplification could lead to an exact view for the final design on the basis of step by step check. This may present a good as well as an exact final design. The simplification of a complicated subject is a main tool if we need to put a good action in this subject. So, the simplicity will be reflected to either the inspection and revision needs or the installation process. The aim of simplicity is a vital tendency for an exact design where the design itself may vary from a place to another due to the local parameters.

2- Harmony

Since the electric station contains many different equipment and device or even components, the arrangement for such components will be required. The said goal means the arrangement could be important for both the components inside and the elements of the station with each other. These requirements may be a main factor for all designs not only for stations but we recognize with such situation in order to apply for the possibility of the design procedure. The harmony of the components in the design may be required in such a subject due to the security needs in the operations with the danger of the presented HV levels in the stations. This will be reflected on the position of each component, equipment distribution, and the electric connections. The harmony can minimize the risk factor in the level of the design where the best design will prevent any danger, generated from the contents of the station design.

3- Reliability

The good design should supply the energy to the either the network or the consumers without tripping so that a power station must be reliable in electric feeding. The reliability is a significant item specially with electric power stations due to the need for continuous flexibility, service duty and the ability for extension. On the other hand, the reliability might be expressed through the reliability factor so that the final design of a station can be easily evaluated. So, the strategy of reliability should be implemented for each component as well as for all steps individually or gathered together.

4- Safety

The safety rules may control the operations and installations as well as the maintenance in order to secure either operators and engineers inside the yard or equipment including insulation, conductors, devices or windings. This subject is a main one specially we work with a High Voltage level where it is a deadly main. Thus, any design for any element inside it should reply all the requirements to put persons as well as equipment as a safe point. This safety may be based on the already known standard specifications related.

In the situation there is also a mechanical safety as well as an electric safety so that safety will be of more important with the nuclear stations. Thus, the regulations may be a restricted one.
This safety related to the earthing systems of the station as a whole or even for each element inside. The known danger properties such as the step voltage as well as the touch voltage would be the main two factors in order to save the human either labors or even visitors (general persons).

5- Protection

It means the protection against faults which can be appeared during the normal operations of the station. Also, the protection must realize the safety of either the equipment or the human. Then an automatic protection against short circuits in the station or any part of the station and its elements or even in the power system. This protection could be needed too with wrong operations due to the low level of persons sometimes. The automatic protection for either each single circuit or the overall tripping systems could be important to cover all the possible faults and consequently any generated new faults with a future extension.
The automatic protection appears to be a main tool for the design which means that it is a part of the exact design for a station either power station or substation. Whoever, the subject of the design of the protection system for a generator or a transformer is more complicated and consequently for the station as a whole will be more difficult. This leads us to the importance of the simplification in the protection schemes while the discrimination for the protection tripping circuits will be charged in the design.

6- Stability

One of the most important factors in a design of any equipment or a system may be the stability. This stability should cover both conditions such as static or dynamic operations. Then, if we work with the electric stations, consequently with the power stations, a dynamic part of work could be investigated. This is a fact with either operations or clearing a fault or even during the switching processes

during the network operation. The system should be stable for any disturbance or mistakes. It must face any troubles without unbalance, relatively.

7- Economic

Engineering design differs from the pure scientific solutions in that the price is a relative factor. Then, the engineering design is always depending on the economic solution in order to cover either normal or emergency operations. Hence, the cost plays a great role in the final result of the design computations to find out the best engineering solution. This means also that we can stop for a long time with two designs in order to differentiate and choose one.

8- Disturbance

Generally, the disturbance or the possibility of its presence may make a noise for the quality of the design. This means that the design could consider the most suitable connections and arrangement in order to minimize the disturbance possibility with operations. This operation would be in a wide scale to cover all possible conditions either normal or abnormal operations. This is required to save the conditions of switching in order to get the most convenient solution. On the other side, we may face a situation that we can not avoid at all since we must try to Minimize it to the lowest possible level.

9- Quickness

All wiring installations would be suited with the standard specifications in order to cover any leakage in the elements. Although this leakage may be referred to the operation process after installation, it can be presented through the error factor. The connections and wiring should reduce the error factor to a minimum level during operation in order to bring a station to the stable zone without risk or even to the lowest possible risk. The great meaning for such risk would be to save human first although the general aim could be the reduction of all types of operation errors.

10- Operation Errors

It is required to protect the system from either the external or the internal faults so that a fast clearing for short circuits during operations or even under emergency conditions may be a case. Quick fault clearing may be necessary for most elements in the power system in spite of the contrary in other cases.
These ten items as given above are very important to realize a good design for not only the electric stations but also for any engineering system and they all or some of them can specify the general profile for the design. They may be a good tool for comparison and choice although the design should be implemented according to the standard specifications related to each element.

1 - 2: ELEMENTS of A STATION DESIGN

An electric station would include more and more elements that may vary in performance or in the style. The purpose of each element could be differs from each other but we are going to discuss the most important components in such a design. The most of them will be active with a sensitivity factor, that may changed with time for each one, as well as it may change for each component from the other one. The elements of a design would cover all requirements needed for the station and so even for a part of the station.

1- Major Equipment

This part of a station may be the main requirement as it means the alternators as a unit as well as the main transformers inside a station. Also it may be only the connectors for a connecting style station or only transformers for some other types according to the purpose of this station. Otherwise a station can contain many other elements not only these main items but also many other small minor parts. These minor parts of a station have a great meaning for a design not less than that of the major part. Consequently, a good design defines both the majors and the minors parts of a station.

2- Measuring Instruments

The measuring instruments are a main tool to work, in an accurate manner, with a power system although a station may be appeared as

an individual action inside. Always, we need to measure the main parameters such as voltage, current, power, energy, power factor, transient performance and others. Therefore, a measuring tool will be necessary in spite of the High Voltage (HV) and the Extra High Voltage (EHV) levels presented in the station. The Ultra High Voltage (UHV) also, must be considered in such a process. The measurement can be fulfilled through the known current transformer (CT) for the current measurements in large values while the voltage transformers (VT) would be required for the voltage measuring. All other parameters could be deduced by these two fundamental values. This may depend on their values or in other words on the angle between the two vectors.
However, both the characteristics and the operation profiles for the design as a whole and for each one individually must be studied well before applying the design process. This investigation may be proceeded on the scientific level so that the tools of exact design can be derived.

3- Protective Devices

The protection as a title is a great field alone but the design of a station may depend on such protection schemes. However, the protection include large number of devices that differ from each other, the sensitivity and discrimination concept for such protection system would be controlled and adjusted according to the parts of the stations. On the other hand, the devices, working for the protection purpose as relaying, protective circuits and scheme will be benefit to act with the design. The style of protection leads to a suitable out lines for the proposed design although the protection design is a later step inside the station design as a whole.

4- System Characteristics

System characteristics contains different shapes of operations that depend on stages of installations and testing procedures related to the application of operation. Otherwise, the system is a large or not while it contains different types of stations or where the center of the loads in the network.

Also, the aim of the proposed station inside the network will affect the style of the design at the end of application. This means that the operation planning, maintenance plan, points of connections to the network are a vital proposal for the design itself. The importance of the Electric Station inside the power system as a whole and its voltage level relative to the system are needed for the aimed design.

1 - 3: TYPES OF STATIONS

The electric stations can be classified in different ways while the station itself contains many items and components. The stations in general occupy a large area of the land so that the good engineering solutions save this area of the land. The stations in the past sited outside the city zone although it is now is a great problem due to the raising of utilization of electric energy. Then, the stations became inside the population zones where citizens live. Although the station induces a danger area such as electromagnetic waves around or the explosion possibility of some parts and components inside, it is very important to install. Thus, we can treat such a subject in a concentrated view although it is based on a high level of Engineering. It leads us to specify some of the important parts in the field of electric stations and systems so that the types of electric stations may be tailored into:

1- Door Style

Door type of stations goes to the site type of the station that means the allocation of the station on the land. This could vary for different reasons such as the price of land or the characteristic of the site such as a marine site or on a surface of land or on a mountain or hills. The door type of stations can be classified as it may be based as a parameter in order to cover the performance of duty. Generally, it contains two basics types:

I- In door

The Indoor type of stations is a simple shape for the implementation of a station where the elements of the station must be compressed in distances to reach to the lowest cost of such a station.

This means that the station is installed inside a building and, it is usually, used up to 66 kV & even 110 kV level. It is suitable for P. S. and its elements. Requirements for such stations mainly are: (Control room; Boilers, Stores, Measuring devices, Measuring instruments, Workshops, Compressors, Pumping stations, gas suppliers). The indoor style could be defined as a vertical installation type where we must minimize the area of the building so that the connections go to up and down (1^{st}, 2^{nd} Floor and so on), where such cases will be explained later.

II- Out door

When the power of a station is increased the level of the voltage would be higher in order to keep the current within the standard values. Accordingly, the insulation will be greater so that the station may not be impracticable to be install inside the building. So, the installation of a station in this case is done in the Yard without buildings so that it is suitably normally for the voltage level of 66 kV and above, i. e. for HV and EHV or UHV levels. Although the HV is applicable for out door stations, sometimes it is implemented for 11 kV. It is suitable for sub stations too.

2- Loading Style

The load capacity according to the load curve characteristics appear to be a vital subject. This load curve may be planned either statistically or specified to a certain condition. This includes the number of loads, type and the performance of variation where the sum of the full loads supported on the station.

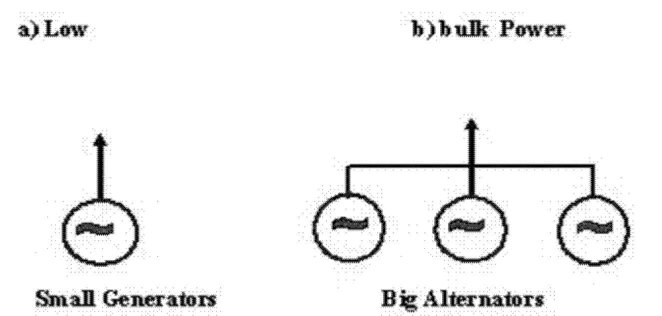
The load curve is a clear title for the design of an electric station according to the concept of the station. The loads either coming or out going can be specified within the parts of the station. This may be written as follows:

a) Generation

It is necessary to determine the rated power of a station and the proposed power factor for the operation either planned or statistically. Also, the number of units in the power station is a

required factor as well as its type such as nuclear, hydro or steam. Otherwise, the performance and the site of the station will be important factors. So, the place of connection to the network and the purpose of the station installation would be cleared before the action of the design process and calculations have been applied.
The characteristics of generating a power either for a large scale or short may have - to a certain extend - a meaning. Hence, the study of the load curves will be a positive factor in the design so that statistical presentation may be important. So, two mainly types can be considered as a small or big generating power - as illustrated in Fig. 1 – 1 - where big power may be generated from many or multi of small generators or even many big generators sometimes.

Fig. 1- 1: Types of generating Electric power



Many types as nuclear, steam, gas, water, wind, solar, mass, hydro-electric are presented as well as they work well under all circumstances. It may be of large capacity or small, multi voltage level or unity. Auxiliaries for a power station (P. S.) included in many branches and fields but the main of them could be as are: (Repair rooms, ventilation, offices, lighting, measuring, Fire alarming, elevators, control units, ...).

b) Transformation

The transformation step is applied to a network in three levels where the first comes at the generating end to set up the voltage to the rising value. It is illustrated in Fig. 1 – 2 where the location of transformers should be between the load and generators. This is necessary to minimize the current carrying capacity through the conductors of a system (A circuit). Secondly when we need to transmit the power from a place to another (from a city to another) while the last stage comes at the distribution system where we need to minimize the voltage level to that one to be suitable for consumers. The sum of loading as a load curve at both sides of a transformer, and sequentially for all transformers will affect the distribution of loads according to the load curve. This means the best choice for loading during the 24 hours a day. It indicates the most suitable connection will depend on the load curves supplied by a station.

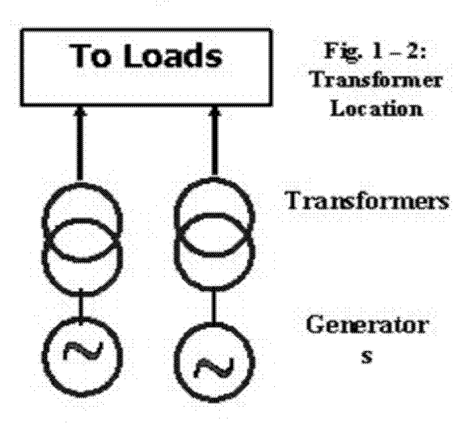


Fig. 1 – 2: Transformer Location

Then, a Sub Station is defined as the transformer station which deals with the conversion of power from a voltage level to the other. It includes the possibility of voltage control or power compensation.

c) Switching

The switching process induces higher level of voltage over the nominal rated values. It is defined as internal transients because it is induced due to the switching processes in the network. The induced voltages may appear with sudden tripping as well as when the

normal closing and opening of the circuits in the network. Fig. 1 – 3 presents some locations for the required circuit breakers in the electric circuit of a power system in different cases. In other words this means that the switching affect the system either circuit breakers or the elements of the station. Therefore, the contents of circuit breakers with the automation can be considered to prevent the high level induced as possible.
On the other side, the switching processes in the network will produce a special effect if it is related with the generator loading. The swing characteristics would be a great tool for the stability of a generator to work well in the network. The electromechanical transients may induced so that the stability condition would be checked. Also, the electromagnetic transients must be covered by the insulation level of the station.

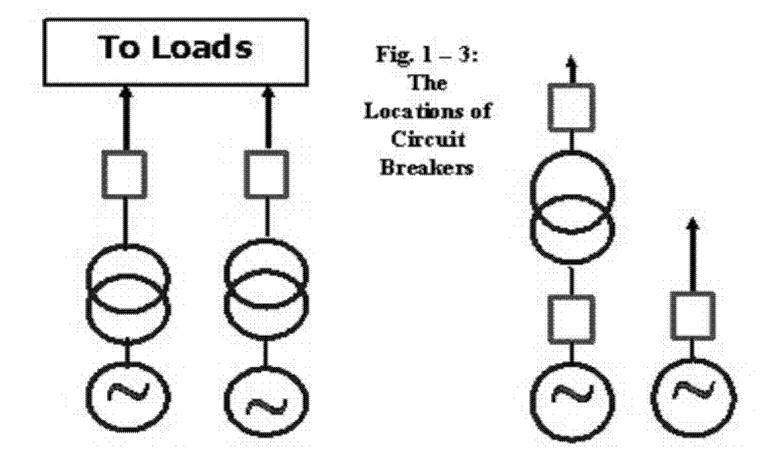


Fig. 1 – 3: The Locations of Circuit Breakers

d) Supplying

Feeding principle is a vital tool for the application of station in order

to get the best distribution for loads. This will depend mainly on the shapes of the load curves according to the standard load curves. Thus, the feeding process depends on the shape of loading with respect to the load curve performance as given above with generators or transformers. A balance between incoming loads and outgoing loads instantaneously where the load curve gives a repeated variation in the load with time. The load curve characteristics can play a great role in the process of the design. The choice of the single line diagram by the designers as well as the concepts of connections between different loads inside the station would be affected.

3- Components

Various elements and components are required for the design while there are some of them are the most important. Then, it will be important to study the main items in spite of the needed other components. Some of these important components may be investigated and tailored as it will be given in the present book, The main items that must be included in the design of a station are shortly given below:

i- Single Line Diagram

It is the connection between different parts of the circuit of the station where it clarify the distribution of the power through the circuit branches. It takes the steps of connections between different points in a power system as it comes, for example, in the connection diagram of Fig. 1 – 4.

ii- Switch Boards

The terminal connections can not be applied directly without control concept that must confirm the protection for human and the technical implementation for connections. These connections are collected and made inside a place (panel) which is defined as the switch board (Panel board). The switch boards can be classified according to the voltage level or as due to the type of loads or as for the type of purpose. It is simply tailored too into different types according to the type of application where they may be given as:

a- Power Switch Board

The power panel boards related to the connections of the power circuits which normally characterized as a 3 phase system either for the distribution level 380 V or for the high voltage load applications level of 3.3 or 6.6 up to 11 kV level. They may include the lighting switch board as a special board for lighting or another for motors only.

b- Control Switch Board

Control panels are required for the circuits of control where their potential may be less than that for the power one, where it may be for the control circuit of the field windings of a generator or for the voltage control of a part in the circuit and so on.

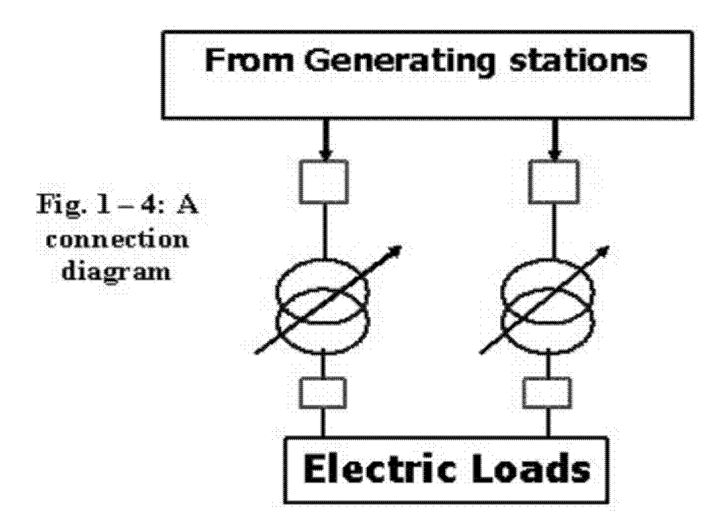


Fig. 1 – 4: A connection diagram

c- Protection Switch Board

These boards are specified only for the protection schemes and circuits as they must be far away from any other circuit to avoid the mutual or any other effects. This elimination between the protection circuits and others is an important strategy for the installation of the wiring inside a station.

d- Measurement Switch Board

The measuring panel boards are important in order to determine easily the electric parameters of the station. So, the situation of the station may be recognized while the fundamental factors and parameters can be recorded. Sometimes, the parameters required can be given as drawings where it is convenient to be computerized in last time. This concept is a appeared in the second half of the last century.

e-Telecommunication Switch Board

However we interested in a power station or others, the light current presence must be introduced. Although the networks treat the bulk of powers, the control systems need to indicate all major factors at all points of the power system. This is the information technology base that depend on telecommunication concepts in order to transmit a signal of measured parameters to a specified point. Since a station contains a lot of components, a great amount of information should be treated. Thus, many connection for the telecommunication purpose must be inserted so that their connection may need a switch board or more than one.

iii- Circuit Breakers

Circuit breakers are the automatic tool for cutting the electric spark of the current in the circuit, which may be generated due to the process of cutting the passing current.

It is important to identify that circuit breakers are also the mean to close (switch on) or open (switch off) an electric circuit. When the power is high of a supply in a circuit the cut current would be switched on or off under the normal processes of operation, a circuit

breaker must be designed too to overcome such high values of currents. On the other hand, the short circuit currents would be at high values even for circuits with low values of nominal carrying currents.

iv- Bus Bars

Bus bars are a main part of the scheme in the electric circuit of a station although it is mainly can be considered as a point or a node in the electric circuit. It represents the possibility for variations in the shape of the electric circuit for the station so that it may become a good tool for the variety considerations in the design process.

v- Measuring Instruments

Both Current Transformers and Voltage Transformers come as the main instruments in a stations where the need for sampling the danger high values of current as well as the values of voltages. These instruments must be indicated in the station circuit according to the design proposed.

vi- Control Wiring

An electric station would be placed on a large area where the equipment as well as the generators and transformers are allocated within a large distances inside the station. This brings another application induced due to the far distance between the equipment and the control room so that a wiring is required for the control circuits inside the station. The control circuits are mainly distributed because they play a fundamental role for the operation of elements of the station such as circuit breaker. This extended too to other purposes and so on.

vii- Grounding Systems

A grounding system is important for all installation of electrical equipment and devices in either domestic electric circuits or any other types of circuits. This strategy may take more and more importance with the bulk crowded equipment because the carrying current capacity will be at a higher level. Therefore, the

implementation of grounding systems inside an electric station would be necessary in order to cover the danger of presence of the touch voltage as well as the step voltage. Then, different styles of earthing systems may be seen in such locations but mainly there are two types of grounding and earthing. These styles may be tailored as:
a) The grounding to neutral zero potential in the earth and this may be applied through:

i- Local

This type of earthing can be installed according to the international standard specifications. Also, these standards will be explained next in the present chapter.

ii- Grid

The grid earthing systems must be installed in the stations either power stations or substations. This grid is very necessary to confirm the low earth impedance inside the station in order to protect human before equipment in the station.

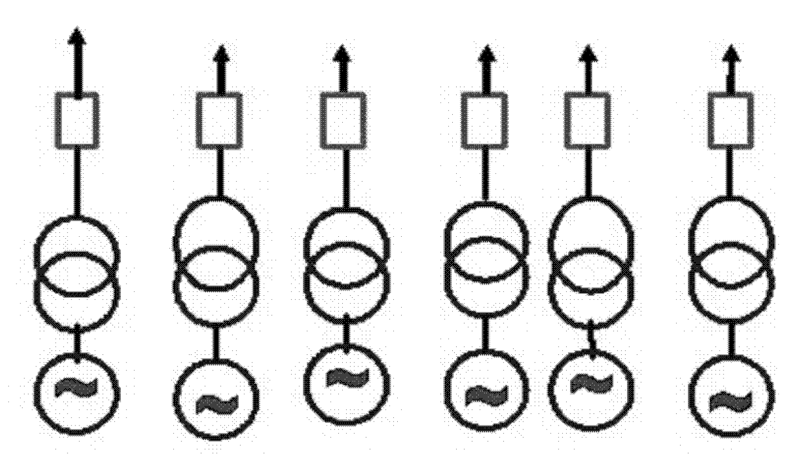


Fig. 1 – 5: A Main Generating Alternators

b) The grounding above the live conductors (phases) in order to protect the equipment in an electric station and all of its elements as well as of all its parts against any possible discharge due to lightning strokes. This earthing type would protect human from any touch voltage specially at moments of short circuits.

4- Classification

After that, station classification can be defined as:

a- Main Power Station

This type of stations will be the big one because it cover the base load in the daily load curve of the system as a whole. Otherwise, it may be operated for all the time as it can feed other stations inside a power system. Also, Such type of station may be varied from traditional stations to a modified one. On the other hand, this station may be a hydro station or thermal stations either steam or gas or nuclear power station. In small individual networks this main station may be a thermal one.

b- Auxiliary Generating Station

Nowadays, a new strategy for the energy raw has been considered although there is no problem in the present time. It is seen that introducing new types of energy mainly in our life must be a main point in the future of energy on the land. It is important to connect the renewal energy stations (Such as wind farms or solar stations) to the network. Such stations cannot act as a main P. S. but they would be helpful in the countries where these energies are cheaper. This may be expressed electrically as shown in Fig. 1 – 6 in order to be a circuit view in all cases.

c- Standby Power Station

Nowadays, such standby stations may not be presented because it is a lost power in every time. This station may be put for either the emergency conditions during the normal operation of a network or for the different locations with an emergency type of loads. The

standby stations goal is the un traditional load which may be related with national or religious holiday. It also, may cover a certain place for a small different time as well as some places far from the main networks. Such stations are usually of a Diesel type.

d- Transformation Set Up Station

Such type of stations includes mainly a power transformer that may be one or more. This station take the generated power from the generating stations on the generating voltage level to send this power to the far distance from its location. Such cases are illustrated in Fig. 1 – 7. This process is important in order to minimize the power loss in the transmission step since the station raises the voltage level and consequently the current will be decreased.
This classification is needed also for the adjustment purpose of the protection devices, specially with the directional power flow protection. It also, may be necessary for the distance protection in order to determine the stages of tripping.

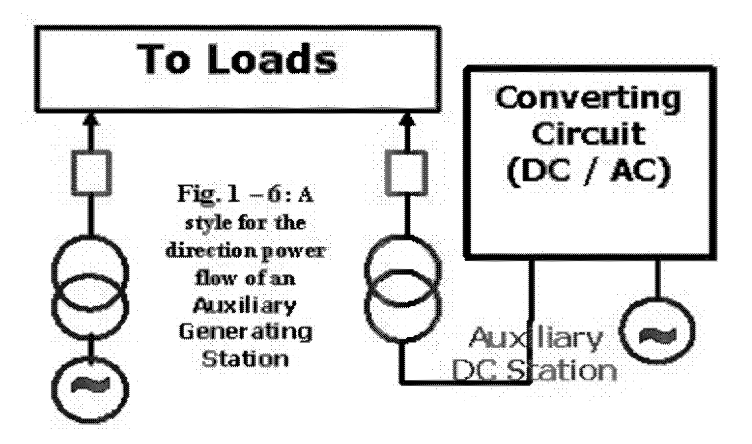


Fig. 1 – 6: A style for the direction power flow of an Auxiliary Generating Station

e- Transformation Step Up / Down Station

The transmission Set Up / Set Down Stations may be required for the power flow variety during the different operation cases because the direction of power flow may be changed (Fig. 1 - 8).

It can be from a station to a variety of some loads through some links. This connection would be through a transformer station where the power flow may take a certain direction towards the load in most cases of operations. However, in some cases the direction of power flow must be changed from a generating place to another that may oppose the direction of current through a transformer station. This means an emergency condition sometimes while it may be a case of the normal positions of operation. The transformer station must reply for such conditions where its input / output powers may be reversed in the direction for the nominal rating of transformers. This type of a station can be installed in the middle points of connections where it would be usually far from either the power station or the service terminals (Fig. 1 - 8).

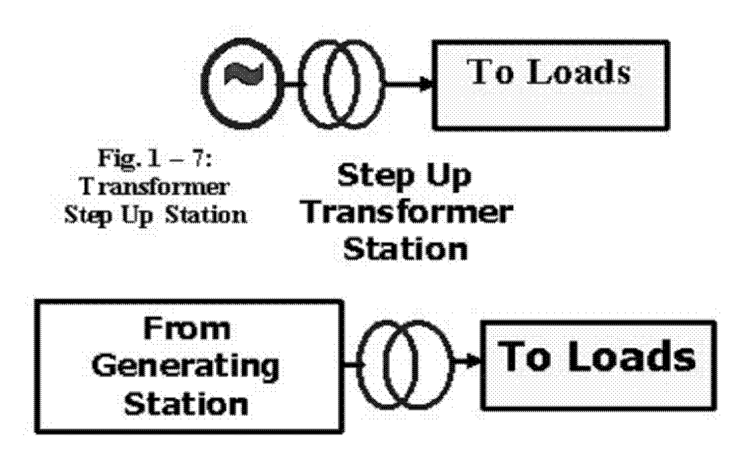


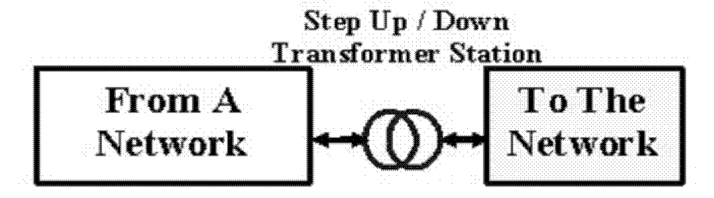
Fig. 1 – 7: Transformer Step Up Station

f- Multi Service Step Down Station

Distribution Stations would be required to supply loads at all

consumer terminals. It is characterized too with the radial supply distribution system so that the interconnection between feeders would be disappeared. The voltage may still be higher than the service consumer voltage level or sometimes it will be the same.

Fig. 1 – 8: A Transformer Step Up / Down Station



For the Distribution Multi Service Step Down Station, the direction of power flow is illustrated in Fig. 1 – 9 where it can supply another terminal distribution station besides loads directly at a medium distribution voltage.

g- Distribution Industrial Step Down Station

These stations would be of a special characteristics in order to reply the requirements of such industry. The type of transformers may be designed for such a purpose. The location for such stations is always at the beginning of the factory loads. The voltage level may be at high voltage or higher.

h- D C Distribution Station

The D C stations are mainly needed either in the industry field or in the research scientific institutes. This may expanded to the university or schools. Such stations would be treated with a special accordance in order to cover the style of loading.

j- Converting Station

A Converting Station would be of importance meaning when we need

to make a connection between the A C generation side and the D C generation.

Fig. 1 – 9: A Multi Service Step Down Station

Step Down
Transformer Station

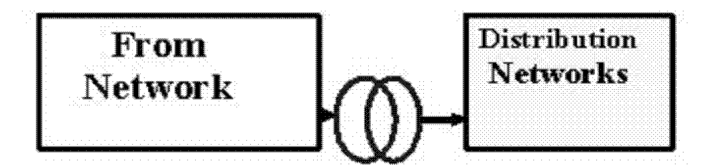


Table 1-1: Transmitted Power Performance

Voltage (kV)	Surge Impedance of 400 Ω	Surge Impedance of 300-315 Ω	Surge Impedance of 250-275 Ω	Max. Power MW	Max. Distance, km
35	-	-	-	-	50-60
110	30	-	-	25-50	50-150
220	120	160	-	110-200	150-250
330	270	350	-	300-400	200-300
400	400	500	580	500-700	600-1000
500	600		900	700-900	800-1200
750			2100	1800-2200	1200-2000

Generally, this may be the next generation installation in the national power systems in the world. Therefore, with the appearance of the wind farms as well as the solar stations – as a generating station - we would manage the connection between them to get a united power system. This station would be required to connect the wind stations with the thermal stations or other in a united network as given above in Fig. 1 – 6.

It should be mentioned that practice defines some fundamental rules that are considered. Otherwise, the transmitted power is directly related to the transmission distance as it is given the Table 1-1. The list in the Table contains the surge impedance besides. It is seen that the Kelvin's law may not be needed because there many other factors takes a role in the design of a transmission system.

1 – 4: LOCAL EARTHING SYSTEMS

Since the electrical equipment and all electric tools are touching either the persons or the land (that having a voltage value not equal to zero), the protection of human who work or use these tools and equipment should be realized and insured. This protection would be against the induced voltage at the surface of such electric devices where its value may reach a dead value. So, all metal points on the electric tools or devices and equipment should be put at a forced zero potential value. Consequentially, a special type of connection must be applied in order to realize this condition so that a protection system can be inserted. This system may take different shapes or styles although the aim is the same and so, the different standard earthing systems are considered.

The local earthing would be important inside a station in spite of it is a distribution style system. This is due to that the station itself will be as a consumer at the same time because the station will need to the different loads of the normal consumers. Thus, the local earthing beside the grid systems of earthing would be necessary to specify in order that the implementation of earthing may be danger sometimes due to the presence of the zero sequence circuits inside the faulty conditions.

The installation of an earthing network inside a station will be of great meaning not only to protect the equipment but also to protect the human labor inside it.

On the other hand, it is very important to review the always check values for the earthing resistance of the grounding system of the station. Then, the station must be regularly register the value of earthing resistance of the devices and equipment inside because the resistance may be increased suddenly due to any break in the

connectors (conductors) of the earthing system. The value of earthing impedance should be located inside the limits of the standard specifications.
Otherwise the standard specifications determine some fundamental earthing systems such as (TT, TN and IT), which would be briefly indicated. Then, the meaning of the letters that name the systems proposed above would be defined according to the explanation listed in Table 1 – 2.
So, the second letter of the main symbols of the name in this region can be presented as given in the Table 1 – 3.
The earthing systems may contain also another modified earthing systems that can be briefly indicated in the following points.

Table 1 – 2: Meaning of the Symbols in the first character of the first name of main earthing systems

symbol	Meaning
T	Direct connection between the point and the Earth
I	No direct connection between the point and the Earth except that the high resistance (with high value in order to consider it as an open circuit)

1- Basic Earthing Systems

There are three types as given above where we would explain the aim in two of them.

Table 1 – 3: Meaning of the Symbols in the second letter of the first name of main earthing systems

symbol	Meaning
T	Direct connection between the point and the Earth, without the consideration of the system is earthed or not.
N	The connection between the point and the Earth through the neutral point of the system

a) The First Earthing System IT

It may be defined as *protective earth* (PE) due to the appearance of such conductor (Fig. 1 – 10.)

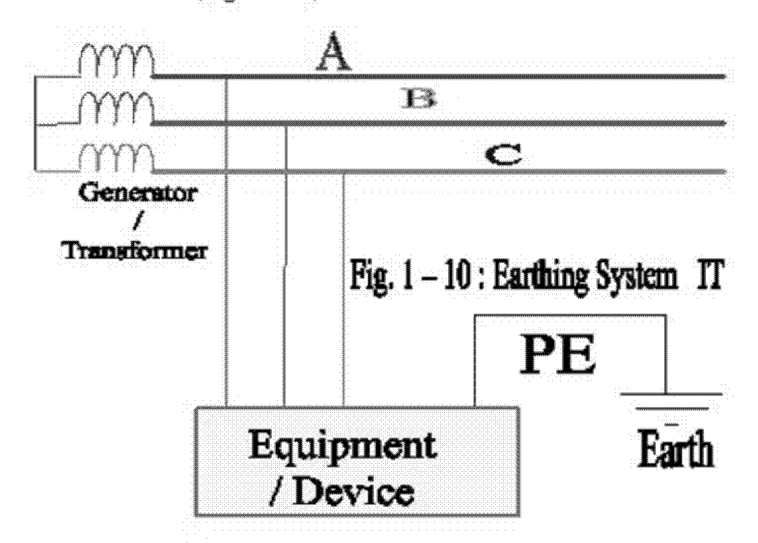


Fig. 1 – 10 : Earthing System IT

In this system the human labor or other persons are protected against the touch voltage due to the electromagnetic as well as the system protect the electric circuits failure. In this case the phase failure due to the breakdown of insulation will touch the earth, then, the tripping circuit has to trip the circuit according to the over current protection. Consequentially the circuit breakers (means of cutting circuits) must trip the main supply out of the circuit.

This system of earthing IT is illustrated in Fig. 1 – 10 where the metal bodies of equipment and devices are earthed without any direct connection with the neutral point of the supply itself through the wire PE. This system should confirm a low value for the neutralpoint of the power system which must be not

exceeded. The metal of earthing rod would be buried as an earthing rod gold due to the low value of its resistance but it may be subjected to steel. So, it can be eliminated from this idea and the copper will be the next best material. This system of earthing IT is suitable for electric station because the neural point is far from the earth point. Then, the zero sequence current will not depend on such connection for the earth point.

b) The Second System of Earthing TT

The electric connections for such a system is presented in Fig 1 – 11 where the neutral point as a wire is individual and independent from the PE wire for all lengths. So, both wires N and PE are connected to the earth as shown in the figure.

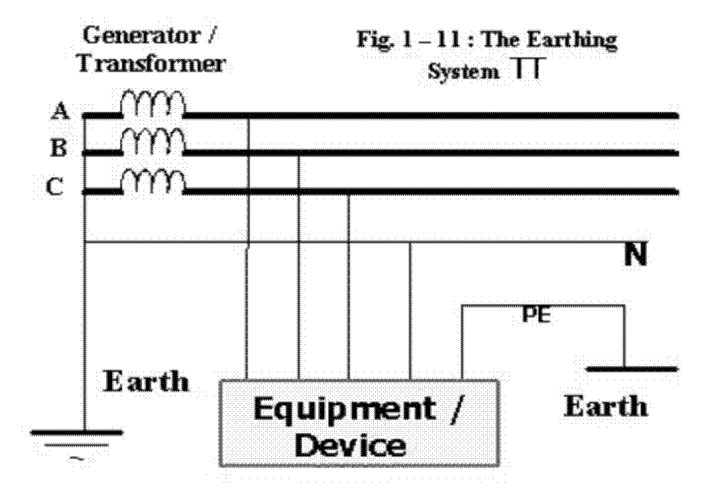


Fig. 1 – 11 : The Earthing System TT

2- Advanced Earthing Systems

According to the basic schemes of earthing systems, the most practical systems can be deduced. They may be tailored in the following survey on the basis of the standard specification.

All of the advanced earthing systems are introduced in the electrical installations of different purpose places either in homes or industry or even in the electric stations. Table 1 – 4 presents the types of these advanced earthing systems shortly.

Table 1 – 4: The advanced earthing systems (TN-C-S, TN-C, and TN-S)

No	Earthing System	Fig. No.	Details
1	TN-S	1 - 12	Both PE & N are isolated conductors where they are connected at the supply only
2	TN-C	1 - 13	The collected conductors together PEN are working instead of isolated conductors PE & N
3	TN-C-S	1 - 14	Part of the system uses the conductor PEN while others use isolated conductors PE & N

This table gives the prime frame for the three advanced earthing systems as they defined in the second column. Also, these systems are a wide spread style in this field. They are presented according to the international standard specifications. These earthing styles are important for the protection schemes and circuit breaker ratings. All systems are used international in spite of some countries, specially the developing countries, are neglecting these systems in some sites. Otherwise, in all cases in all countries we can not ignore the earthing systems in the electric stations because there is a high current at short circuit conditions. Consequentially, the earthing type should be – from the first degree of importance – studied and analyzed for the installation as a whole.

a) Earthing System TN - S

The earthing systems of type TN – S depends mainly on two individual wires (isolated each from the other) for the neutral

point N of the power system as well as the wire PE of metal body (local) earthing in an earthing system. On the other hand the connection between both wires and earth is applied only at the supply terminal – the neutral point of the power supply, so that it may give the facility for the implementation in the distribution networks. This would be of a great meaning with the distribution systems on large area of land. The system is illustrated in Fig. 1 – 12 where it may be applied mainly for the urban and suburban domestic loads even with underground cables. The sheath can be used for the earthing point in most cases.

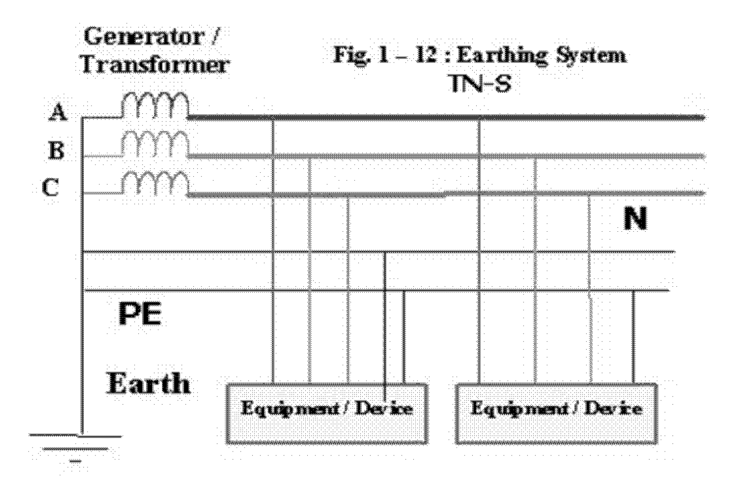


Fig. 1 – 12 : Earthing System TN-S

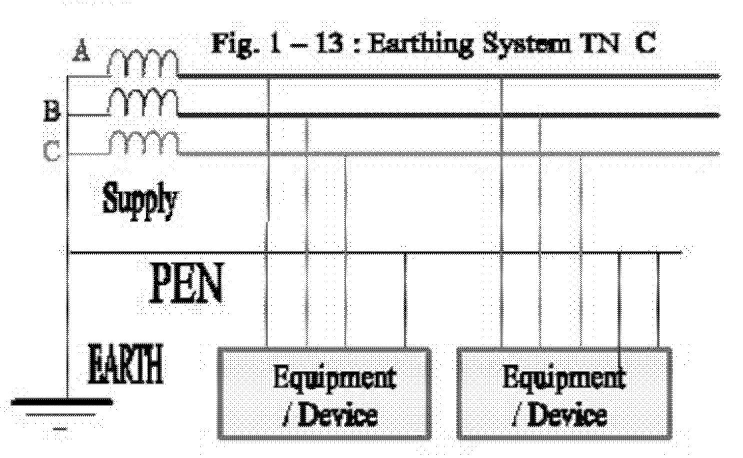
Thus, two isolated wires PE and N are spread along all electric branch circuits of the station would be installed. They should be connected together at the supply neutral point N.

b) Earthing System TN - C

In this system, the conductors (single common conductor PEN) would play the same idea of earthing for both PE and N in the last explained system. Then a single conductor replaced

both wires and consequentially, Fig. 1 – 13 shows the electric diagram for the standard scheme of this type of earthing.
This earthing system TN-C was spread in the old types of power systems in the distribution networks so that it may be replaced by the type S-TN of earthing specially with domestic loads.

Fig. 1 – 13 : Earthing System TN C



c) Earthing System TN – C - S

This advanced system of earthing TN-C-S appears to be the most suitable between all above for most cases. The reason may be referred to the combination between both above styles (Fig. 1 – 14). In this case, we can get a part in the earthing system as the a single conductor PEN for earthing while the second part will reply for the two isolated wires style such as PE and N. This is explained in Fig. 1 – 14 where the connections between the three conductors appears at a middle point in the scheme.
In the case of increasing the current – over current condition – a good safety situation may be realized against the Electric Shocks in spite of the possibility of passing a high current during a normal operation. So, adjusting step could be benefit

in order to cover such cases so that we may need for electromagnetic-compatibility filters. Sometimes, anti surges would be required for different types of antennas as well as with many types of measuring instruments. Thus, this system of earthing needs a qualified scientific study as well as a practical analysis for adjustment conditions.

3- Performance of Earthing Systems

The earthing system is necessary in all cases, even in any place, in spite of the absence of their applications in poor and some developing countries. So, the most important axes related to the subject can be indicated next.

a) Economic Side

The earthing system TN appears to be the low cost level according to the small earthing impedance when it is treated for each consumer individually. In this case a local single earthing rod can be installed. Otherwise, both systems of earthing TT and IT will need for earth leakage protection in order to adjust the level of leakage current to earth (typically 10-500 mA). This will raise the cost of implementation.
Also, the system of earthing TN-C will save the cost of a conductor (either the neutral wire N or the earthing wire PE) in spite of the higher risk factor induced. The risk factor is raised due to the possibility of cutting a conductor (one of both).
A time lag discrimination would be an initial point for the protection tripping circuits in the system of earthing TT such as RCD downstream style on the basis of the second Kirchhoff's law. This means that the summation of currents in the phase lines must be equal to the neutral zero sequence current leading to the equation of currents:

$$I_{L1}+I_{L2}+I_{L3}+I_{N} = 0 \qquad (1-1)$$

b) Electric Safety

In the unbalanced three phase power systems, the neutral voltage

may be deviated from the zero value so that a separate point in the earthing way will raise the risk factor greatly. Therefore, it is forbidden to allow such a condition such as plug or socket. This will be more danger with the application of insulated cables in the earthing wiring if the insulation go to the breakdown point.
Whenever, both systems of earthing TN-S and TT (and sometimes the system TN-C-S) need to earth leakage protection due to the possibility of short circuit between the phase and earthing wire PE or even the neutral point N. On the other hand, this connection is not recommended for the systems of earthing IT and TN-C in order to prevent the false tripping.
In systems TN-C-S and TN-C of earthing , the voltage may be raised to a danger value for the human labor if a cutting point is created between both wires of earthing PE and neutral N. The system of earthing IT is highly sensitive for the over voltages although it is danger with high risk factor if a breakdown is happened in the earthing wires.

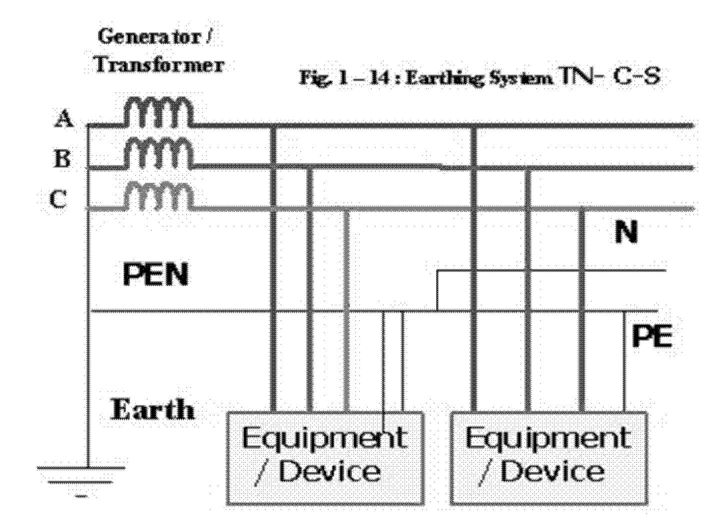


Fig. 1 – 14 : Earthing System TN- C-S

c) Regulation

In all advanced countries such as U S States, Canada and United Kingdom, both neutral point and earthing wire are connected at the terminal of the distribution transformer mainly. This is aiming the safety of persons at domestic loads. The earthing principle may be implemented and installed in the electric branch circuits at the distribution level although the power network supply is different from the normal three phase one. This means that for all types of power networks at the distribution level an earthing concept should be presented. Otherwise the power system is a single phase or double phase.

With workshops as well as the laboratories the earthing systems are very important so that it is will not safe to work without its presence. Also, the suitable system of earthing may be the system IT where it will be more safe in hospitals and laboratories as well as the construction building sites. An additional protection may be required to cover any emergency wrong connection situation. This aim is the main in the service of an electric station.



Chapter II

BUS BAR SYSTEMS

The of Bus Bar means the connection of electrical terminals of wires and cables to be joined together in the shape of a node so that it is practically cannot be implemented as a point. Consequentially, the electric concept of Bus Bar (BB) is a point (node) while it is practically not a point.

$$\text{Bus Bar} = \text{Node} \quad (2\text{-}1)$$

This is a basic point for the electrical installation at all where its use is spread on the universe. Whatever, the implementation of bus bar style is found not only in the electric stations but also in all utilization use. Therefore, the presence of bus bar technology has a wide significant for electrician so that a non electric person can work with it. On the other hand its use represents a small aim in the engineering field when we find that the common rosette is a simple application for the subject concerned. Also, the modern then styles (in the 20th century) as a wired rosette and so on. However, its application for electric stations may be more difficult according to the high level of voltage of the application.

2 - 1: THEORETIAL ITEMS

Since it is concluded that the BB is a point from the point of electricity view, we can treat it according to the Kirchhoff's law as:

$$\Sigma I_{in} = \Sigma I_{out} \quad (2\text{-}2)$$

This also, means that BB is a conductor, which shape may be different in many types. Various shapes are listed in Table 2-1 where the moment of impedance for each shape is formulated mathematically.

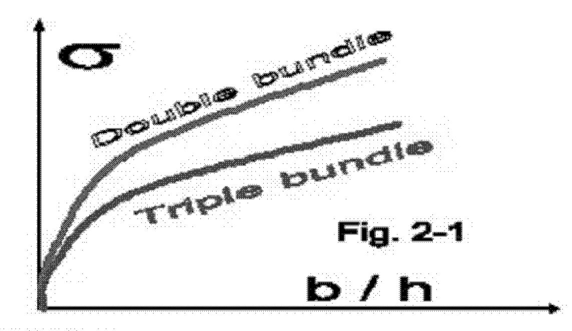
Also, the effect of bundling of the strands of the BB can be more clear from Fig. 2-1 where double and triple bundled conductors are illustrated for the moment variation with respect to the ratio of width to length.

Table 2-1 Some of the standard BB shapes and their moment of impedance.

Poles geometry of BB	Moment of Impedance
a, b	$0.167\ b\ h^2$
h, b	$1.44\ h\ b^2$
	$3.3\ h\ b^2$
d	$0.1\ d^3$
D	$\frac{0.1\ (D^4 - d)}{D}$
b, b	$0.333\ b\ h^2$

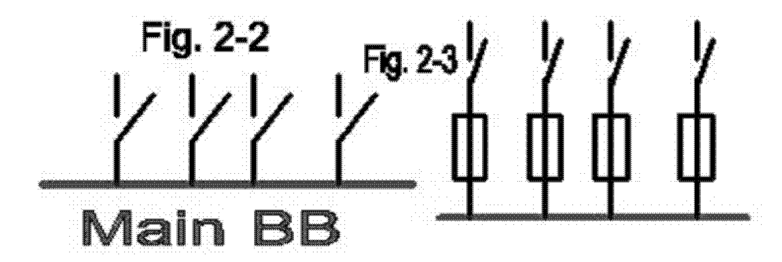
1- Operation Performance

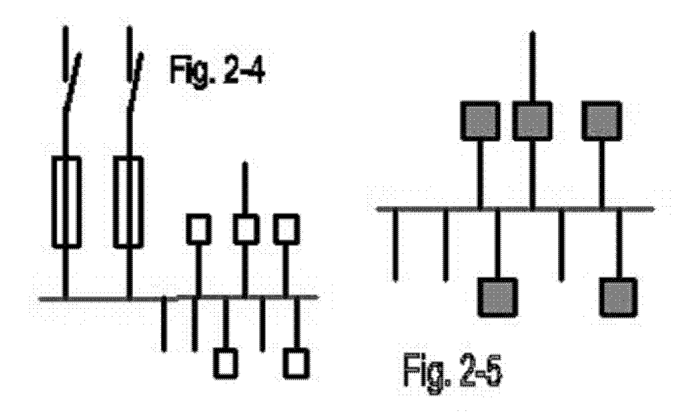
A BB expresses well about all connections inside so that it can be a mirror for a station at all. This indicates that this BB is an important element in the design of a station and then, it should be treated on a high level of study. Hence, a detail study may be explained in the following points.



a) Main Bus

This BB is considered as a main supply due to its basic style in the operation processes although it is a simple one. Nevertheless, BB as a main node in a station appears as a week point from the reliability point of view. So, it will be an important idea to investigate well this item when we find the normal shape of a BB in its simple form (Fig. 2-2). The shown main BB indicates the importance of its role in the electric circuit in the power system.





It is shown that all lines and elements of the electric system are connected to the main bus directly through a switch but with increasing the power the isolating switch cannot withstand against the spark mechanism during short circuit cleared. This increases the connection as given in Fig. 2-3 using a fuse to protect the circuit from the short circuit current. It is noticed that the switch is still presented in the connection for the reliability of operation (ON/OFF) in the normal conditions.
Later with the increase of power feeding the consumers, the circuit breakers (CB) were used besides the presented fuses (fig.2-4) but with the advantages of these breakers the system becomes only with CB as in Fig. 2-5 specially for HV levels. This final shape for the main BB will be modified in the next explaining through this chapter.

b) Auxiliary Bus

Applying the system of main BB some problems were appeared such as the need for cleaning or maintenance or others but without the interruption of the power supply.

Thus, a new thought must be introduced besides the presented one (Fig. 2-6). This leads to the use of a standby BB with the main so that the cost of BB may be duplicated. The new auxiliary BB is a good solution for this problem in spite of its idle presence in the system. The reliability of the system is raised and connections between both main and auxiliary BB will be increased later.

c) Mixed Bus

After that the appearance of auxiliary BB, modified connections and uses are introduced. This mixing for the purpose or the utilization or the need is always going on and still now in such a dynamic condition. It depends on the voltage level or capacity, critical operation importance of the supply or the load or others. Then a more detailed study may be required in the next point.

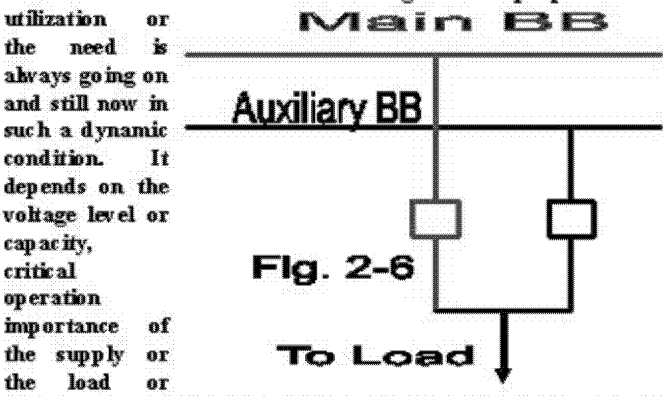


FIg. 2-6

2- Standard Specification

Since a BB is connected in a station to other elements, a standard shape is determined as shown in Table 2 – 1. Also, the technical characteristics would be, too, standardized. So, some of this specifications for a hollow pipe BB (steel coated) are presented in Table 2 – 2. This marks on an easy way for the selection of BB from a present ready standard instead of calculating and then manufacturing it.

Table 2 – 2: standard specifications for a pipe BB (steel coated)

Dimensions	Area	Weight	AC /DC
mm	m^2	kg/m	(A)
13.5-2.25	78.5	.62	75
17-2.25	105	.82	90
21.31-2.75	159.7	1.25	118
26.75-2.75	207.2	1.63	145
33.5-3.25	308.7	2.42	180
42.45-3.25	398	3.13	220
48-3.5	489	3.84	255
60-3.5	621	4.88	320
75.5-3.75	844	6.64	390
88.5-4	1061.3	8.34	455
114-4	1390	10.85	670 (770)
137-4.5	1915	15.04	800 (890)
165-4.5	2270	17.81	900 (1000)

Table 2 – 3: Correction factors for standard BB (hollow pipes with steel coating)

Room Temperature, (° C)	-5	0	+5	10	15	20
Correction factor	1.29	1.24	1.2	1.15	1.11	1.05
Room Temperature, (° C)	25	30	35	40	45	50
Correction factor	1	.94	.88	.81	.74	.67

It is important to concentrate on the given standard values in order to work at different conditions. Otherwise, the given standard values

should be corrected when the BB works at a different condition so that a standard correction factor can be tabulated as listed in Table 2 – 3. It depends on the room temperature.

2 - 2: CLASSIFICATION

The classification of BB depends mainly on the voltage level, i. e. on the power where increasing power going to raising the voltage. This is needed to reduce the rupture capacity of CB in the network which means less cost for the same action. Hence, the different types of BB may be tailored as below.

I- Single Bus Bar

The single BB system may be classified as follows:

A) Simple Type

This simple bus is containing also some different shapes of BB that may be classified as:

1- Single Bus with switches

One of the basic used types is the bus with switches because it is cheaper method for the switching processes. It is suitable for distribution power systems at low individual loads that permit the interruption of the current without the need for the arcing chamber. In this case the switches are low price and low power (Fig. 2-2).

2- Single Bus with fused switches

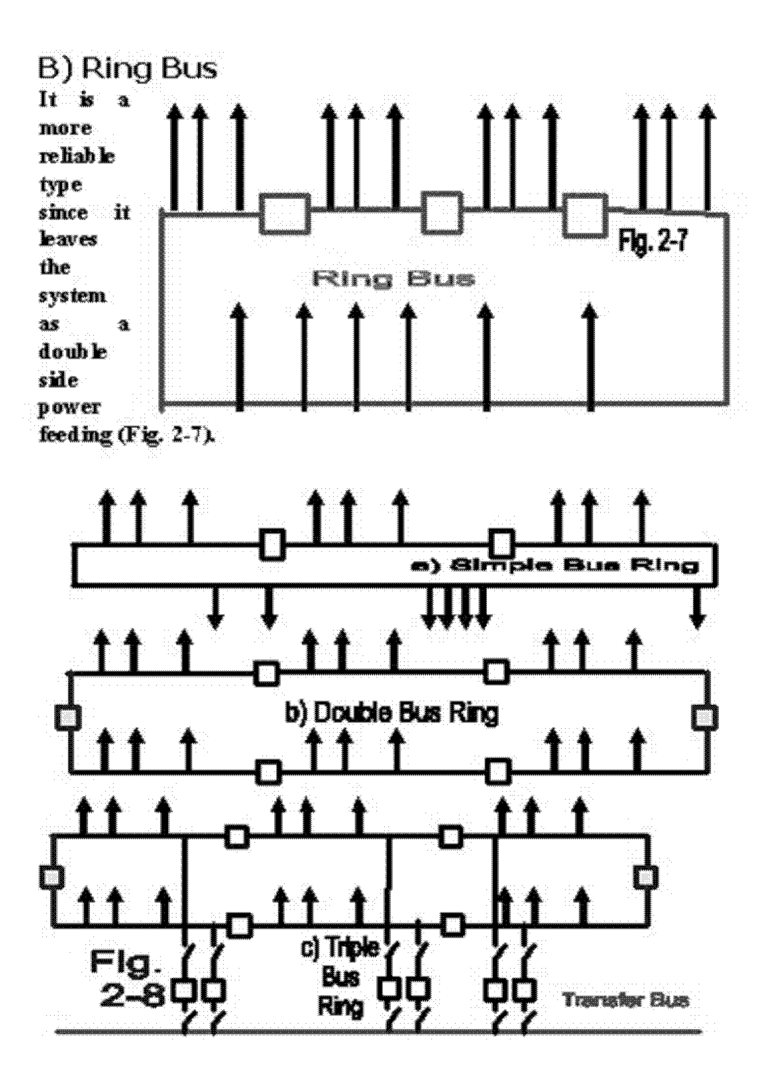
It is suitable for machines and devices on the distribution voltage level in order to protect the equipment connected to the network (Fig. 2-3).

3- Single Bus with CB

It is suitable for all types of loads in the low voltage level ((Fig. 2-4) and in this situation a mixing scheme may be used (Fig. 2-5).

B) Ring Bus

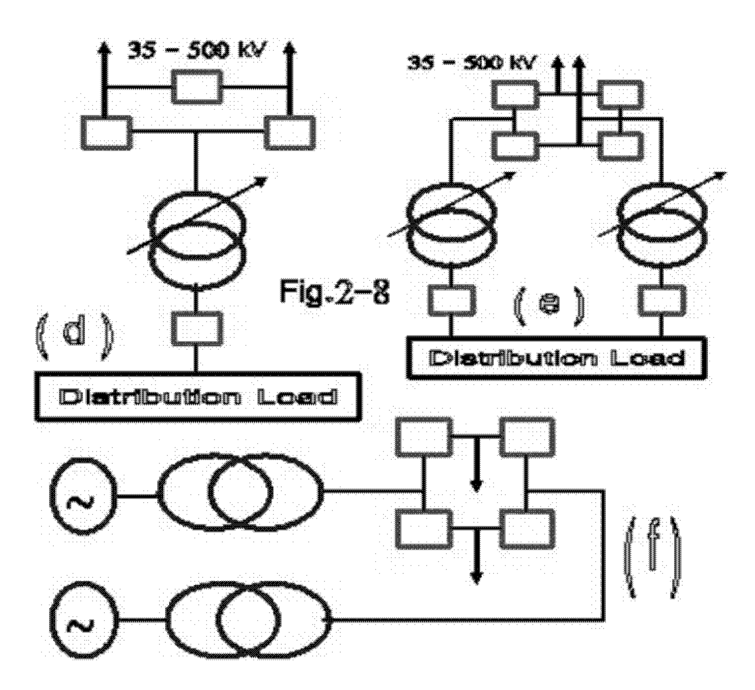
It is a more reliable type since it leaves the system as a double side power feeding (Fig. 2-7).



It may cover the system of important loads but it has a disadvantage as the circulating current if the loop (ring) is closed, It also, may be given in different shapes as in Fig. 2-8 for simple (a) as above (fig. 2-7) or for doubling the cutting in the ring to present a direct two passes (b) or to increase another one (c). There are also, other shapes for the ring type of BB such as the triangle or diagonal concept as given in Fig. 2-8 (d, e) or square style as in (f).

C) Bridging BB

There many connections that can be considered as linked or bridged BB as:



1 - Simple single link BB

It uses a connection to give the facility to feed a load from another near supply as shown in Fig. 2-9. It permits the link connection from single I. L. with or without a CB as given in the figure.

2 - Double disconnected Single link BB

It permits the link connection from two I. L. with or without a CB as given in the figure (Fig. 2-10).

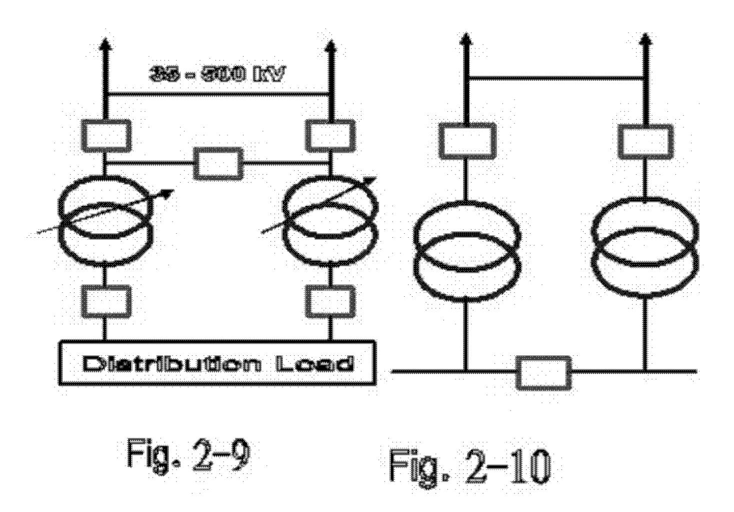


Fig. 2-9 Fig. 2-10

3 - I. L. / CB Linked BB

This scheme depends on the system of double way where one takes the CB with another with I. L.(Fig. 2-11).

4- CB Double link BB

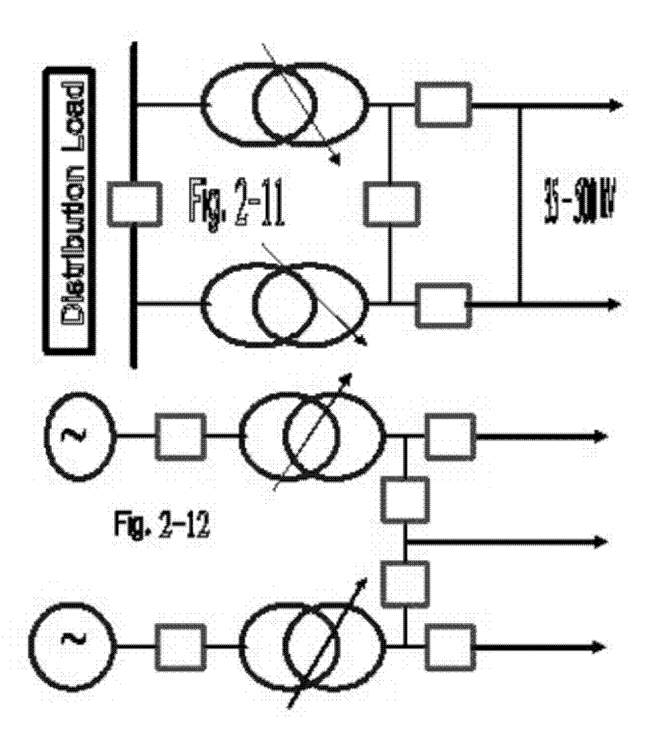
Here we use the CB in the branches that linking both sides (Fig. 2-12).

5- Different Styles

This means various possible connections for different loads according to the type of load as in Fig. 2-13.

D) Practical Schemes

They are many but we can present the most common as: double section (Fig. 2-14), triple section, multi section, star principle.



II - Double BB System

Now, it is necessary to illustrate the meaning of double BB and thus, the next sequence of items may be helpful.

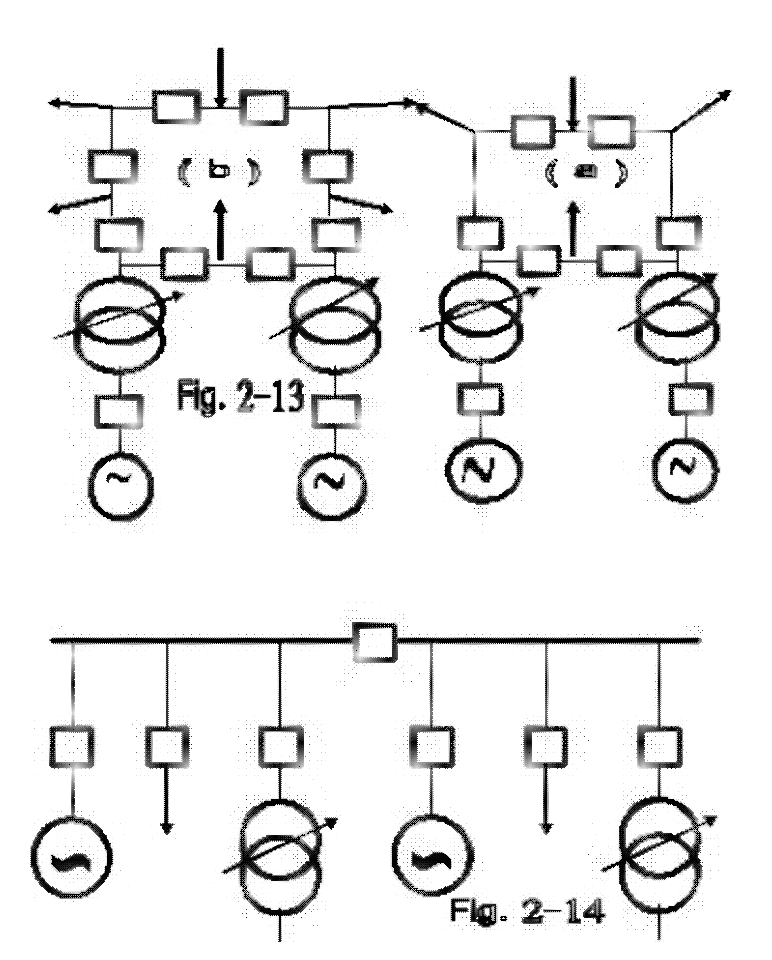
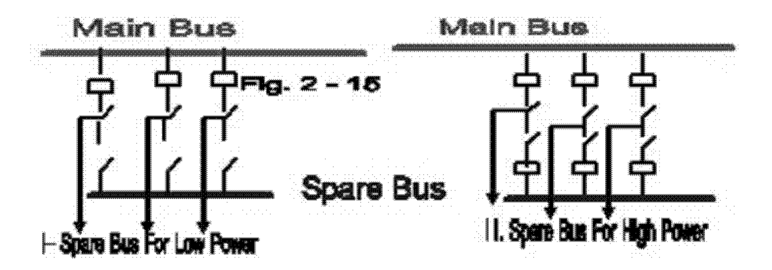


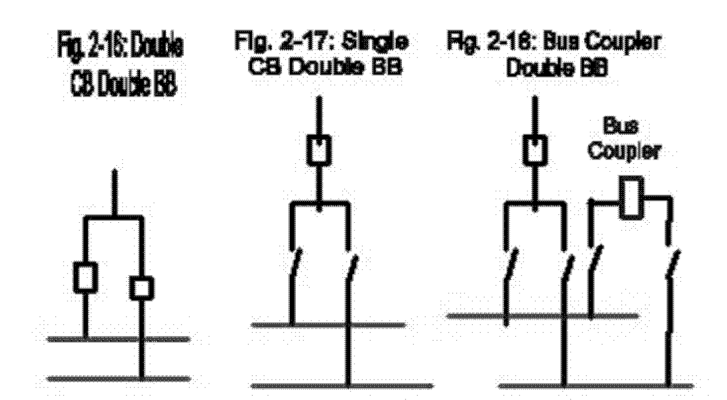
Fig. 2-13

Fig. 2-14

a) Spare Bus

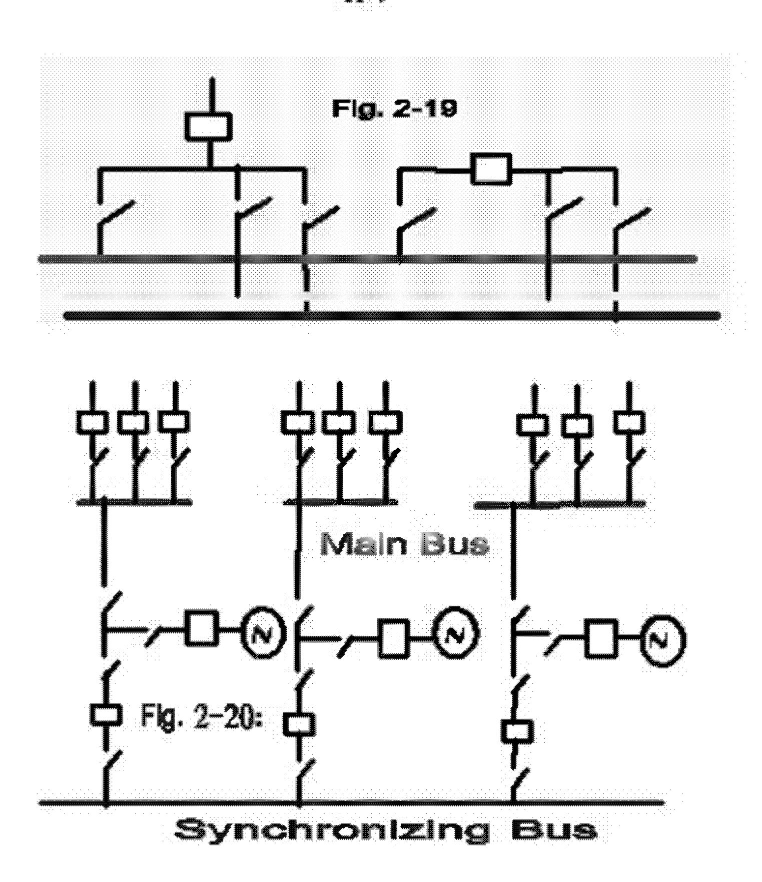
It has been defined above the expression of spare bus or auxiliary BB (Fig. 2- 6) and other two shapes can be added as given in Fig. 2- 15: (i. For Low Power, ii. For Low Power).
This system contains two buses instead of one as given in Fig. 2 –16 where two CB are used in the circuit (each/BB). This facilitate the process of ON/OFF individually for each BB (main or spare) while double BB single CB may be used instead as shown in Fig. 2-17.





b) Bus Coupler

It is a new CB which must be added to the scheme of single BB system to couple the spare BB together with the main one as a double BB system. It should be followed by an isolating link from both sides (Fig. 2-18). Thus, the single CB/Double BB can be used correctly with the insurance of continuous supply.



c) Circuit Breaker Savings

Referring to Fig. 2-17 and Fig. 2-18, we can find that for a circuit connected to the double BB system one CB is saved while it is added as a bus coupler. This means no saving in the number of CB in the circuit. Contrary, if the circuit contains 10 lines connected to the BB, we will save 10 CB from these lines.

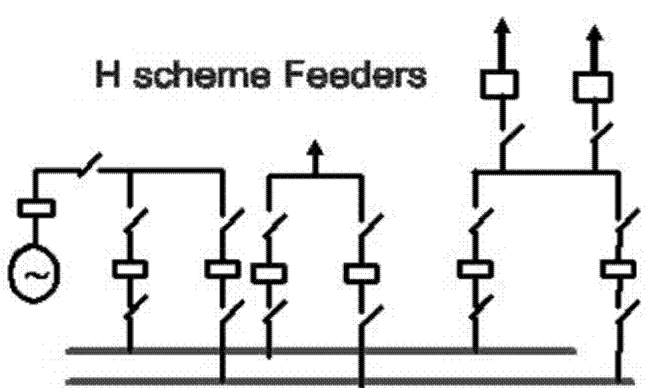


Fig. 2-21: H scheme Bus System

Although a bus coupler should be used, a saved number of CB will be 10 – 1 = 9 CB due to the use of bus coupler (BC). More connection to BB means increased number of saved CB in the system, and so, lowering the cost level for the design.

Firstly, double BB has been applied for standby operation when cleaning or maintenance. With the growth of the power the need for the continuous operation of the spare bus is increased so that it became as two individual stations as single BB. This was a good solution with the raising in the short circuit level at the BB zone

III - Triple BB System

It is known that the growth of generated and transmitted powers is going forward. This leads us to find that the double BB system

cannot withstand with the new growth so that a third bus may be necessary, This means the triple BB system (Fig. 2- 19). Also, it is required for P. S. as a synchronized BB as shown in Fig. 2-20.

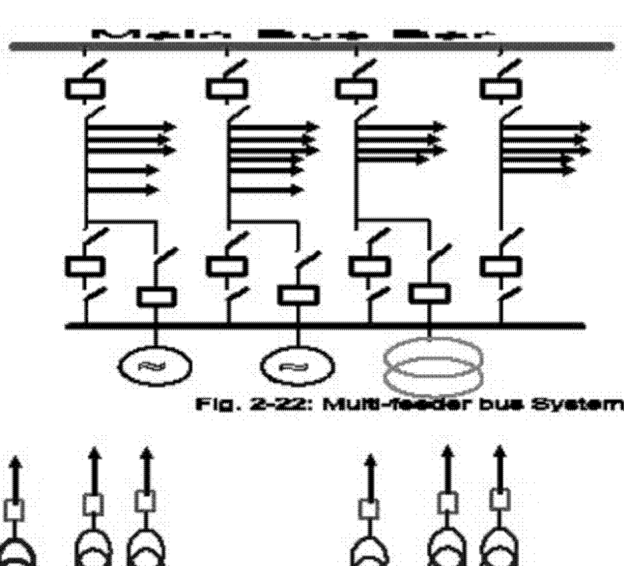


Fig. 2-22: Multi-feeder bus System

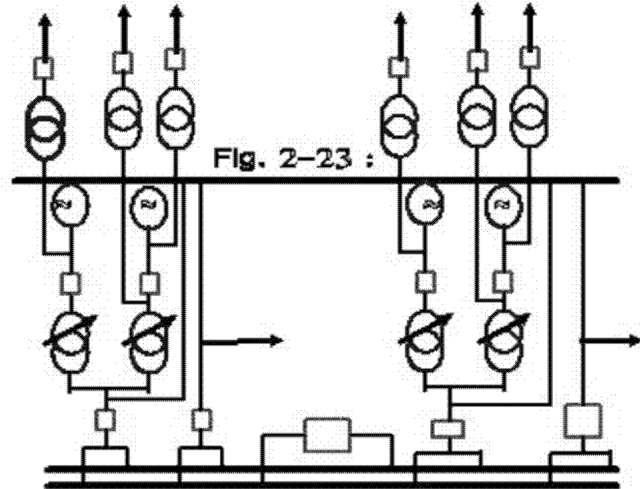


Fig. 2-23 :

IV- Group Bus System

The grouping BB system may be used for feeders as the shape of H (Fig. 2-21) to present a more reliable connection or as a multi-feeder bus system (Fig. 2-22). The grouping BB systems may be defined as a system of connection for a typical types of groups as in Fig 2-23 for the typical grouped radial style as well as the grouped typical transformer connections as given in Fig. 24. It should be indicate here that Fig. 2 – 23 represents a transformer grouping style from another point of view. This last group contain different typical single line diagrams while others may be defined as:

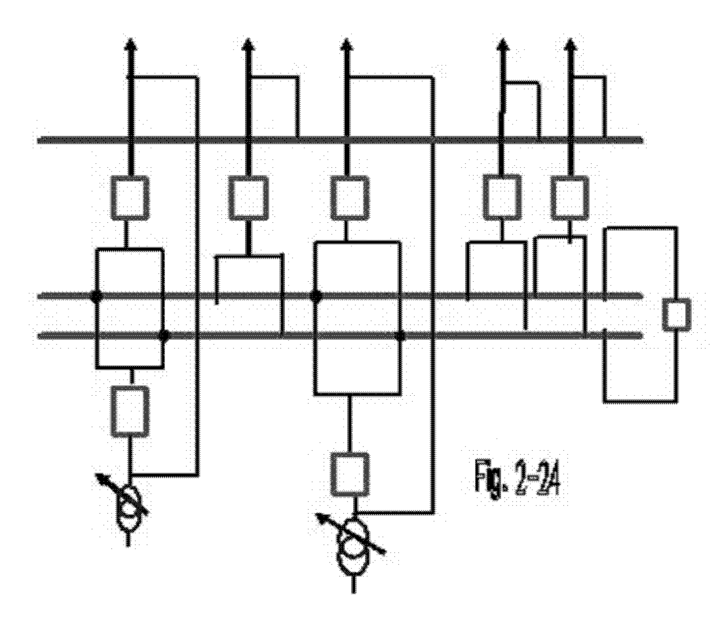
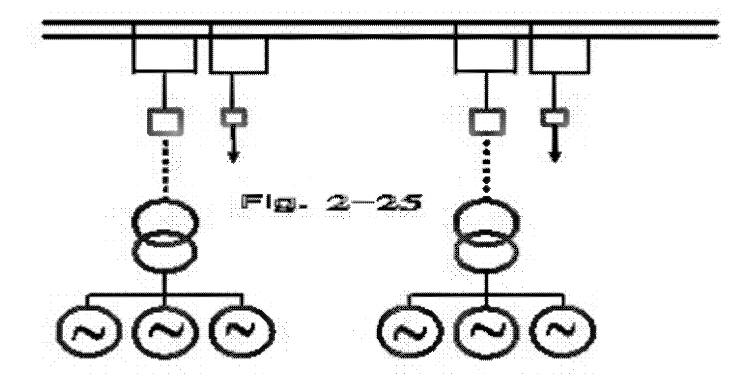
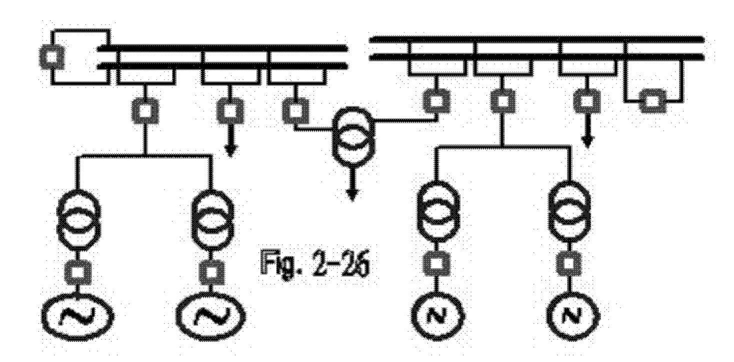


Fig. 2-24

1- Block group type which appears to suitable for power stations, specially the hydro stations (Fig. 2-25).



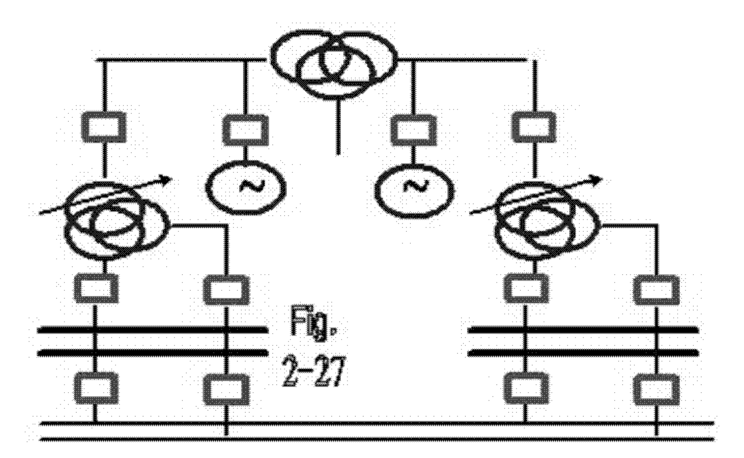
2- Transformer sharing group of Fig. 2-26 that is applied to power stations including many numbers of units of solidly connected performance (large number of generating units).



3- Reactor grouping type where it suits the distribution network for feeders with high short circuit level.

4- Grouped generators style of Fig. 2-25 can be easy used EHV and UHV levels.

5- Double way BB system (Fig. 2-27) where a power station includes a multi way of supply and multi way of loads, i. e. in many directions for loading.



2 - 3: SECTIONALIZATION

As said before for the double or triple BB system and the need for the BC as a tool for the coupling between both BB (main and spare) we repeat the same but with the sectionalization concept. Fig. 2-28 shows the single BB style but it has been divided into a number of sections. This is given again for the double BB system (Fig. 2-29) where the double CB breaker is taken as the base for the drawing.

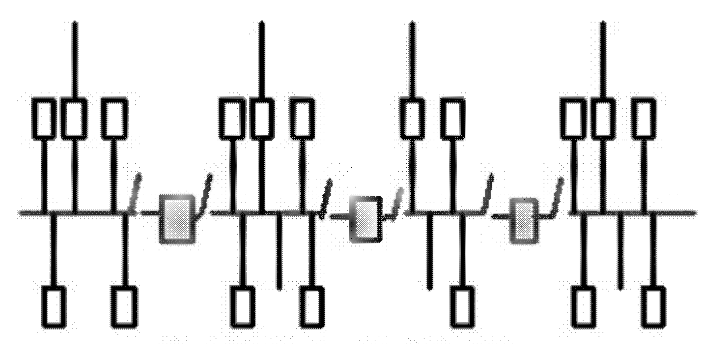


Fig. 2-28 : Sectionalized Single Bus

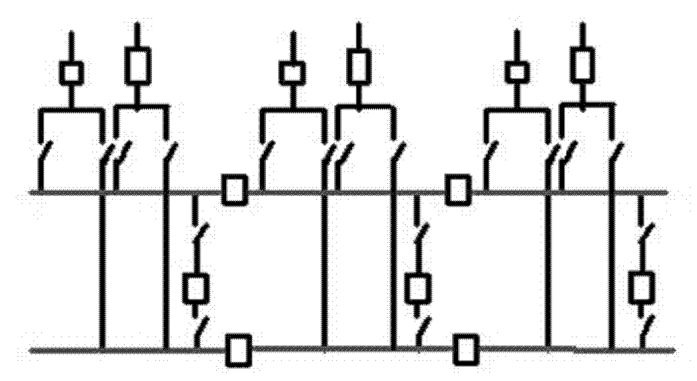
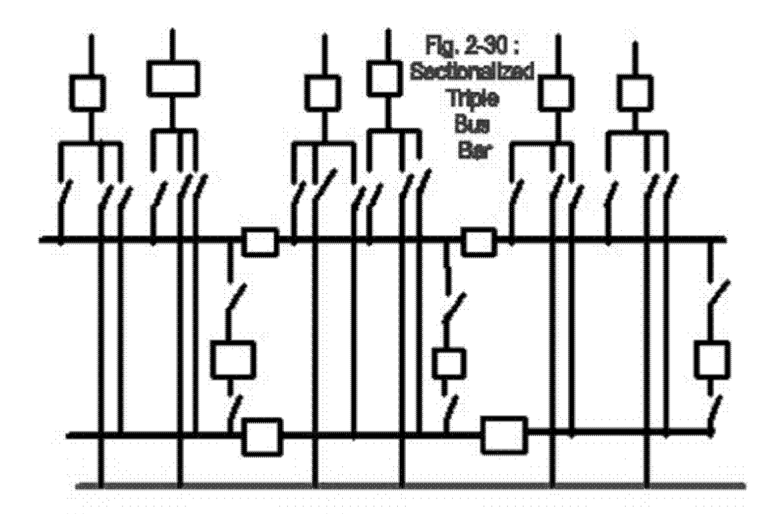


Fig. 2-29 : Sectionalized Double Bus Bar with single bus operation

I- Advantages of Sectionalizing

These advantages may be indicated as:



1- Limitation of S. C. current
2- Reduction of mechanical forces on buses & windings
3- Isolate zone of faults
4- Permit the back up protection against the failure of a breaker at a feeder.
5- Also, it can Isolate Each Gen. & section

II- Bus Tie (BT)

The isolation condition means different applications where the bus tie may be given in some cases, that may appear in various shapes. Bus tie is normally opened part in the electric circuit in the distribution systems and it is normally closed in Transmission systems. Then, it is given for the triple BB system in Fig. 2-30.
Therefore, a bus tie (BT) is similar to the BC because it isolates each section of BB individually. It seen in Fig. 2- 28, 2- 29 and 2-30 where single, double or even triple BB system is applied. Then, on such bases the ring sectionalized BB system can be illustrated in Fig. 2- 31. The synchronizing tie and bus are shown in (b).

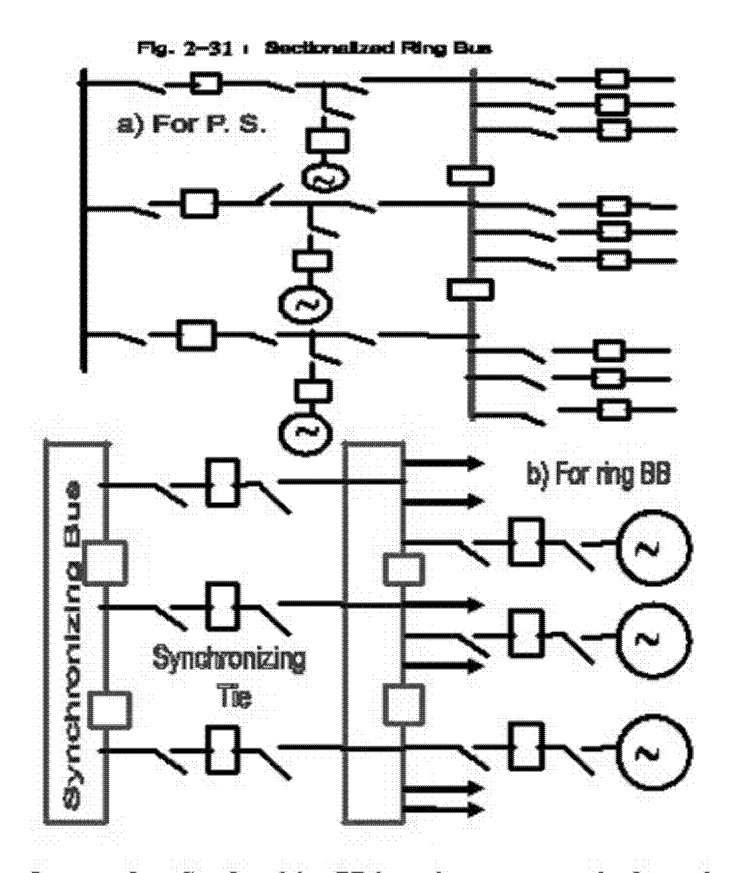
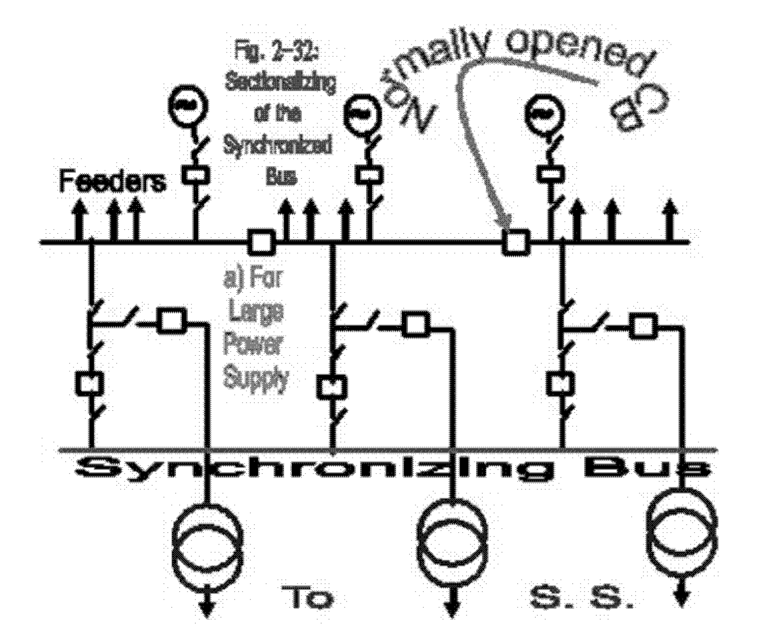


Fig. 2-31 : Sectionalized Ring Bus

In general, a Synchronizing BB is an important part in the station either it is a power station or substation or even a switching station because it is a main concept for the connection of generators to the network (Fig. 2-31).Then, it is given in Fig. 2 – 32 for the synchronizing tie as well as a synchronizing bus. Also, Fig. 2 – 33 shows the same condition for a double BB system.



III- Node Bus Bar

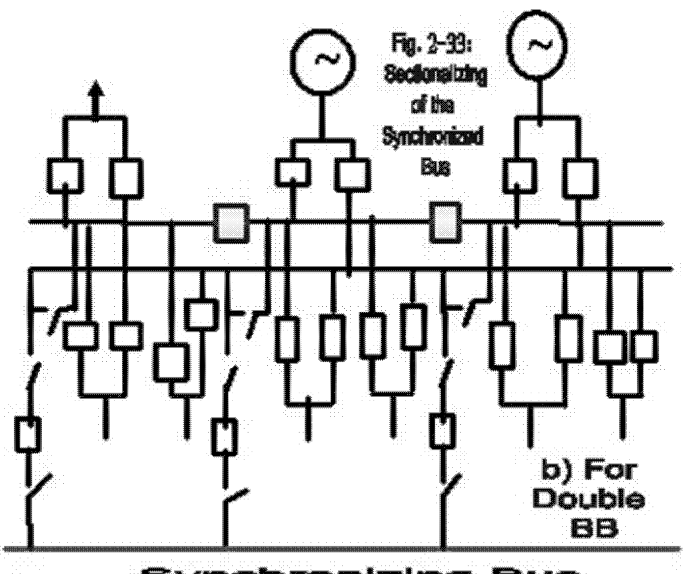
It is necessary to put the main schemes related to the sectionalization subject after the presentation of the synchronizing BB because it was the actual entrance for the section style in the BB. These BB systems may be tailored in the form:

1- Simple node BB

This has been explained before and illustrated well.

2- Solid node BB

This type of BB has been in duty for a long time as it is working stable in all stations. Such a system may be specified as:

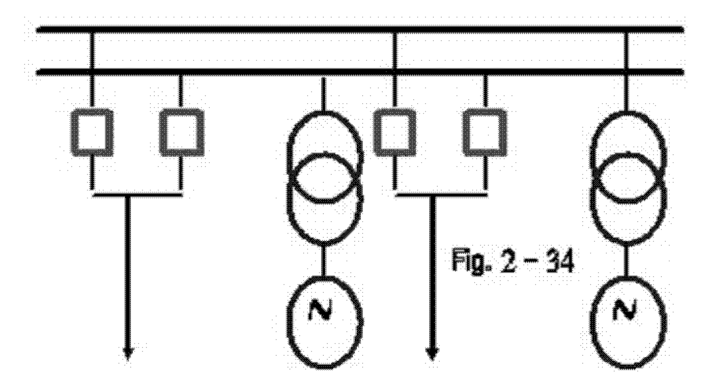


a- *Solidly Connected BB*

It is as in Fig. 2-34 where the BB is connected directly to the alternator unit. The outgoing lines and feeders or transformers should have the CB with BB while the units are connected directly without any CB. The disadvantage in this case will be the independence on the loads.

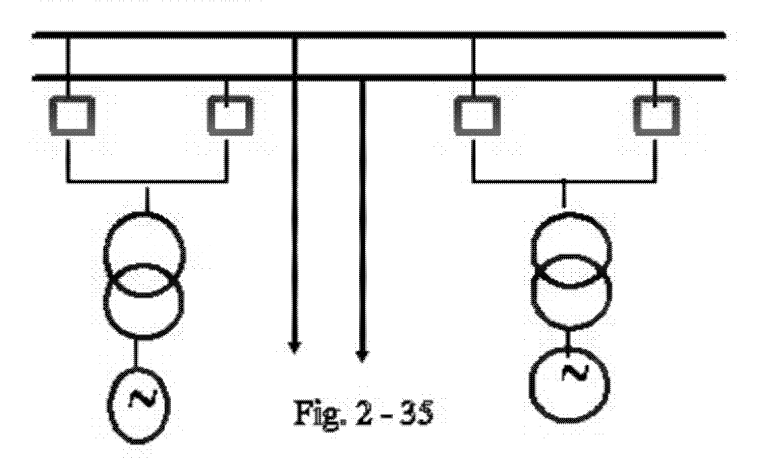
b- *Solid line / BB connection*

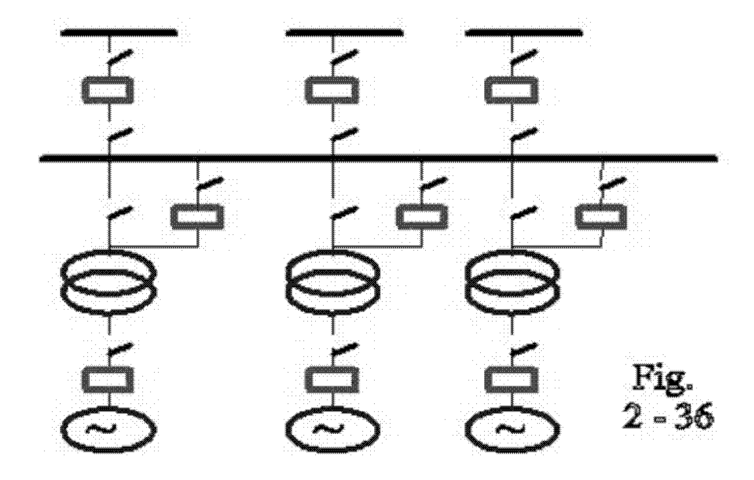
This type of connection would be installed where the CB presence is transferred to the units mainly on contrary to the last one. It canceled the disadvantage above (Fig. 2-35).


Fig. 2 – 34

3- Multi path BB

The most suitable solution for the reliability level in the operation condition may be the application of this concept. This may be classified in the form:


Fig. 2 - 35


Fig. 2 - 36

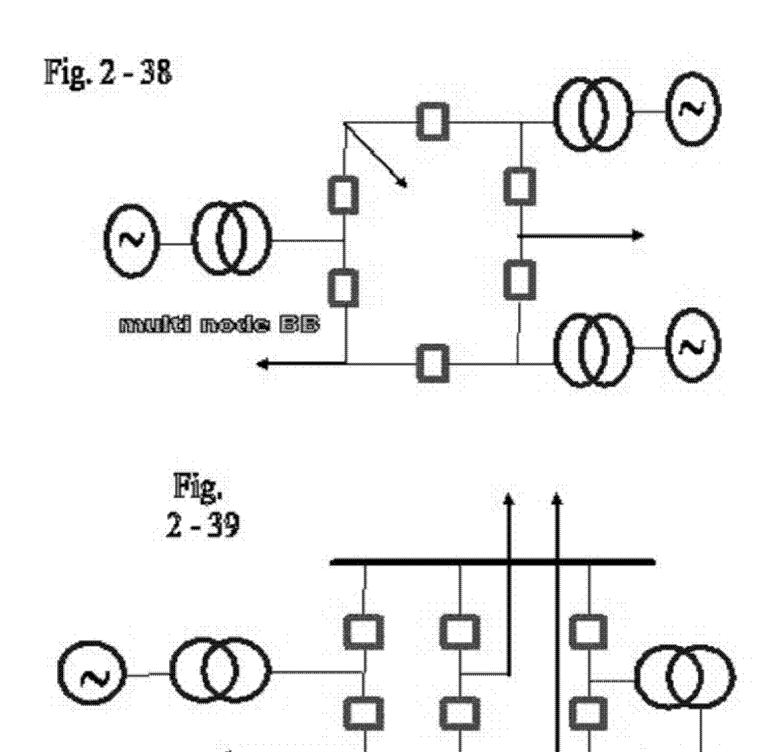
a- *Single input / output style*

It is convenient to the P. S. as Fig. 2-36 presents a single line diagram for a power station.

Fig. 2 - 37

b- *Single input double output*

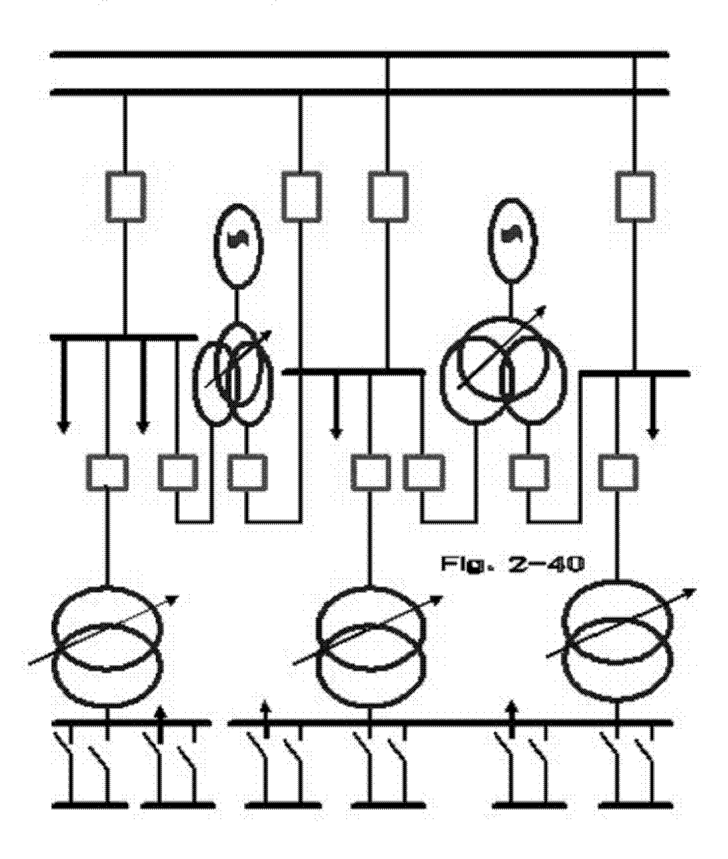
It is suitable where for each input line or supply there are two outgoing lines as illustrated in the figure (Fig. 2-37).



3/2 node BB

c- *Multi-node BB*

This type of BB is more expensive but it works at a high degree of reliability as shown in Fig. 2-38.



d- The 3/2 node BB

It means that for each two input supply branch connected to the BB

there are three branches outgoing from it (See Fig. 2-39).

e) The 4/2 node BB

It represents the input of two ingoing lines while the out going is 4 lines so that it is suitable for the connecting stations inside the transmission system. It will be illustrated later.

IV- Typical Schemes

They may be a lot of connections but we put a sample for illustration as the drawing in Fig. 2-40 for P. S. and in Fig. 2-41 for mainly S. S. Also Fig. 2-42 presents a typical connection for a distribution station. It is shown that both 3 and a 4 winding transformers are applied in the system. The given schemes are presented to complete the idea of changing the performance of BB although it may be believed that the BB is a simple or even very simple subject.

V- Voltage Level

The BB could be specified according to the level of its voltage because the growth of the power takes the BB to a wide change in both use and purpose. Then, the BB can be tailored according to the voltage level in the following characteristics:

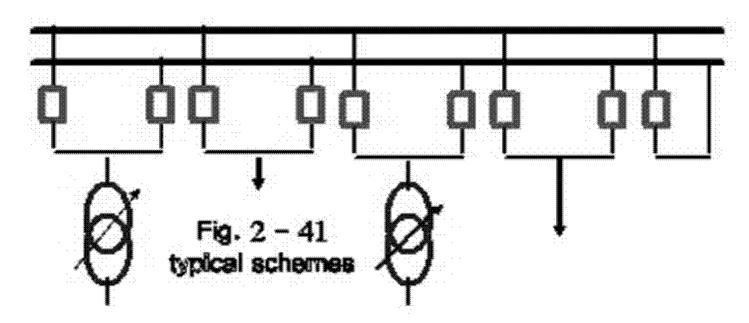
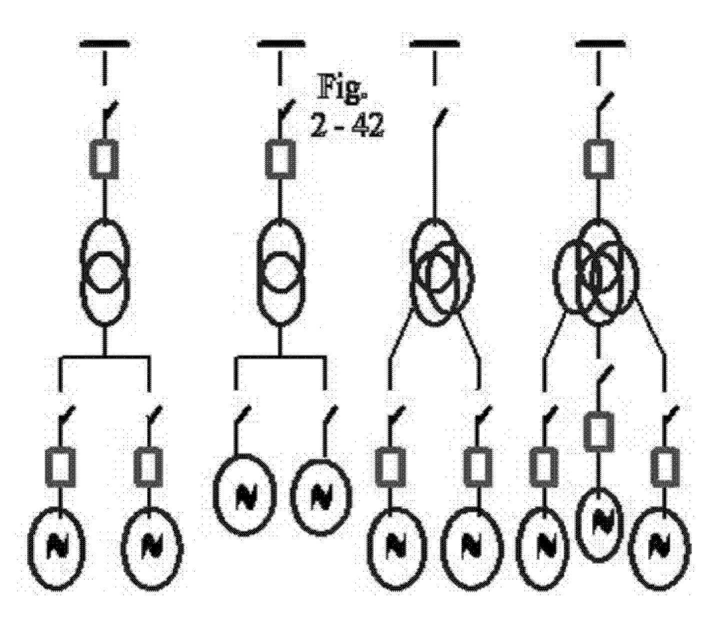


Fig. 2 – 41
typical schemes

a) Single voltage level

This system is the normal which is used always in the distribution

network and so, it is possible to pt such a system in either single , double or triple BB. All the above circuits represents this condition although other types for P. S. can be approved as given in Fig. 2-43. This is called as the single voltage level for the 110 kV P. S. where all units are connected to the main BB.

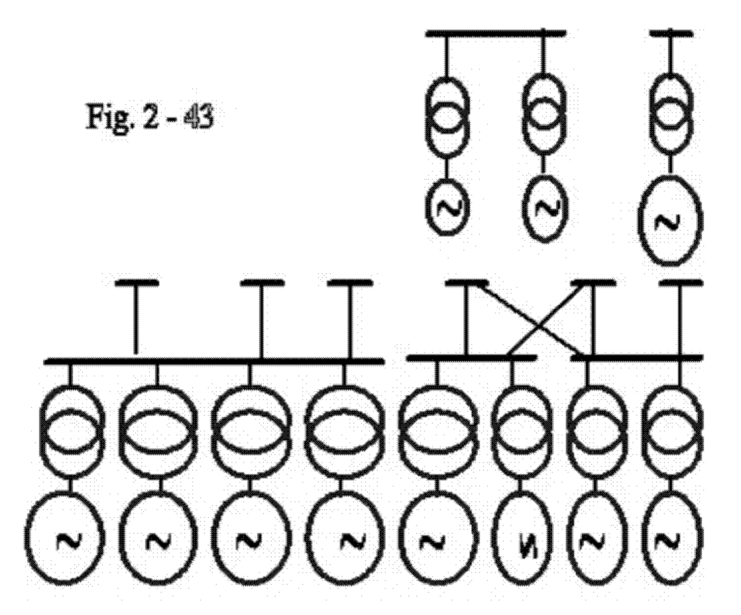


b) Double voltage level

In the proposed case, the voltage of BB may be different at the same side as given in Fig. 2-44 where a three winding auto-transformer is installed between the two sections of a single bus at different voltages of 110 and 220 kV.

This may increase the reliability factor due to the different level of voltages either against faults or the stable balance in the distribution

of operation action.


Fig. 2 - 43

c) Multi voltage level

On the basis of the double voltage level it is expanded to be more than two voltage and Fig. 2-45 brings the circuit diagram for a triple voltage BB (110 / 220 / 500 kV). It is given to the P. S. with a lot of generators connected to the three voltages BB increasing the possibility of stability and we see the auto-transformers are connected as a tie tool between sections of the BB.

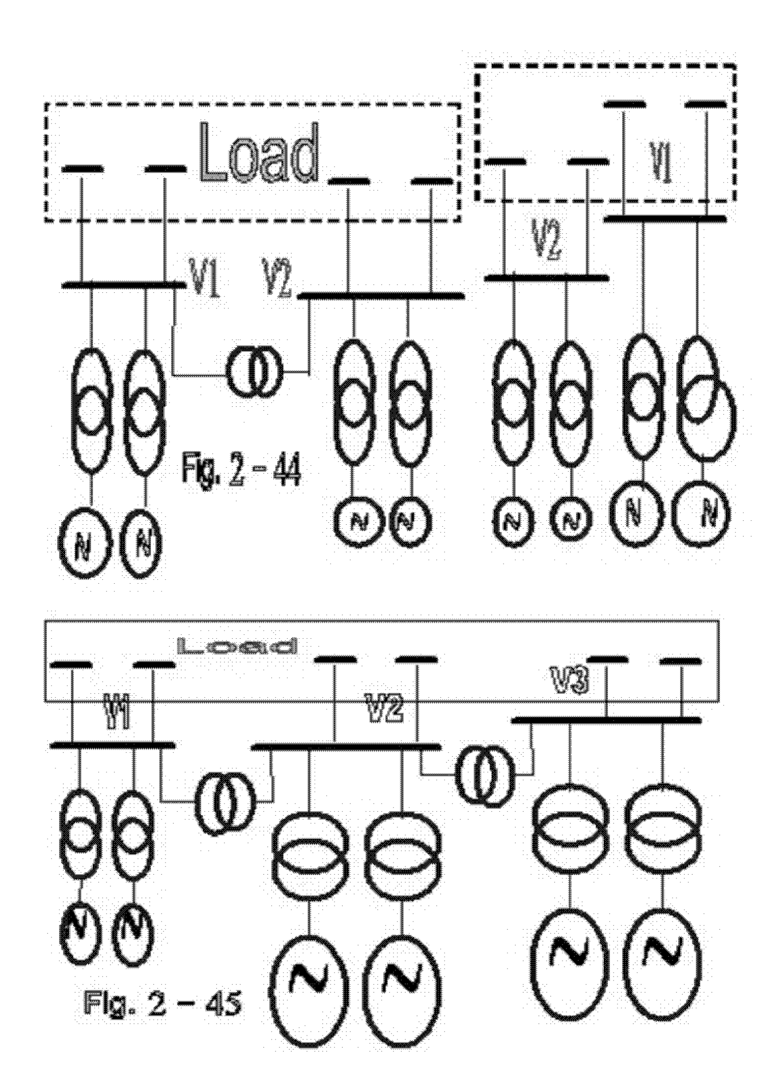
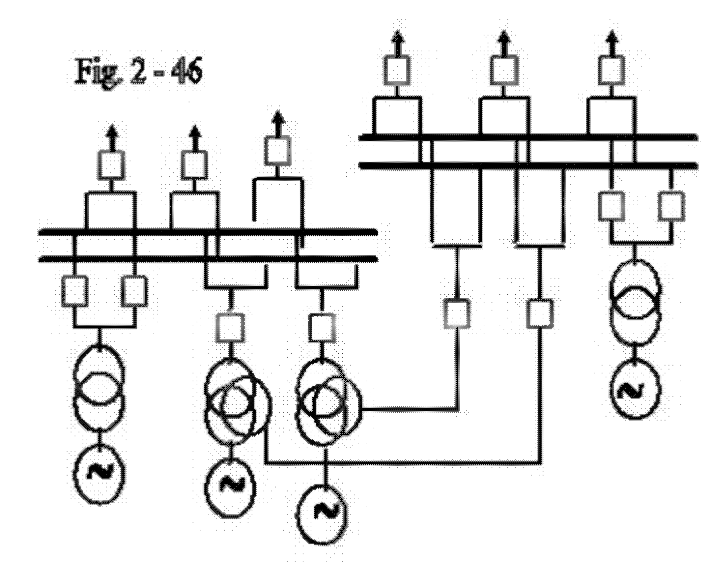


Fig. 2 - 44

Fig. 2 - 45

Advanced connection is drawn in Fig. 2-46 where isolated BB sections are put but an auto-transformer connection between both isolated sections of the BB is decided in two points (not one) Therefore, the sectionalization concept leads the subject of BB more valuable and interesting. This tie connection by transformer windings may expanded to tie more than one section to a certain one and then, a multi connected section BB can be utilized as the interconnected network principle. Thus, a multi voltage level sectionalized BB with a great benefits may be introduced.





REACTIVE POWER

We have two fundamental shapes of the electric circuits as it may be alternating current (AC) or direct current (DC). This means that in electric circuits we may have either AC or DC or both in the electric circuit. This may be found in power systems where main electric power circuits are 3 phase AC type although there is rarely DC power circuits in transmission systems. So, AC analysis could be considered in order to cover the subject as a whole.

3 - 1: INDUCED REACTIVE POWER

Reactive power in a power system must be naturally generated as the network works on AC supply. It is the alternators which have windings. Windings have an inductive reactance that can be translated into a reactive power. This is an important performance in electric networks.

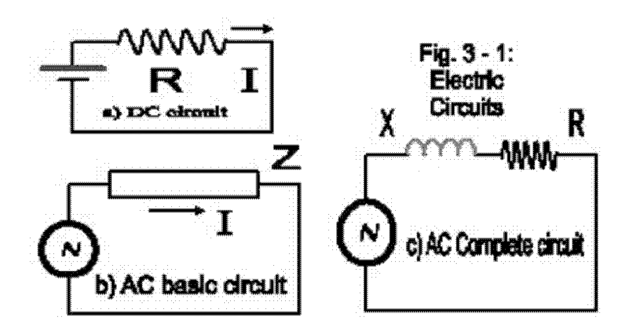


Fig. 3 - 1: Electric Circuits

1- Parameters

The difference between AC and DC can be shortly explained now since Fig. 3 -1 presents both cases of AC and DC as electric circuits.

It is seen that the main parameters in DC circuits are only the resistance R for a current I where the appeared voltage will be

$$V_r = I R \quad (3-1)$$

Then, the voltage and current will be in phase due to the scalar quantity of resistance R and so, the power consumed in that resistance will be

$$P_r = I V = I (I R) = I^2 R \quad (3-2)$$

All these quantities are in phase so that one type of power can be presented where their vector diagrams are given in Fig. 3 – 2. Contrary to DC case, a simple AC circuit is also given in Fig. 3 – 1 while its vector diagrams are shown in Fig. 3 – 2. Thus, it is shown that 3 types of resistance would be appeared Resistance R as in the case of DC circuit with two types added here. They are reactance X and impedance Z.
In AC circuit the first triangle is the impedance triangle, in which we have that:

$$Z^2 = R^2 + X^2 \quad (3-3)$$

This means that the reactance X is not in phase with resistance R but it is perpendicular to it as shown from the mathematical expression (3 – 3). The second triangle is the voltage vector diagram which gives that

$$I Z = I R + j I X \quad (3-4)$$

Where j defines that there is an angle 90° between both R and X.
This equation may be rewritten as

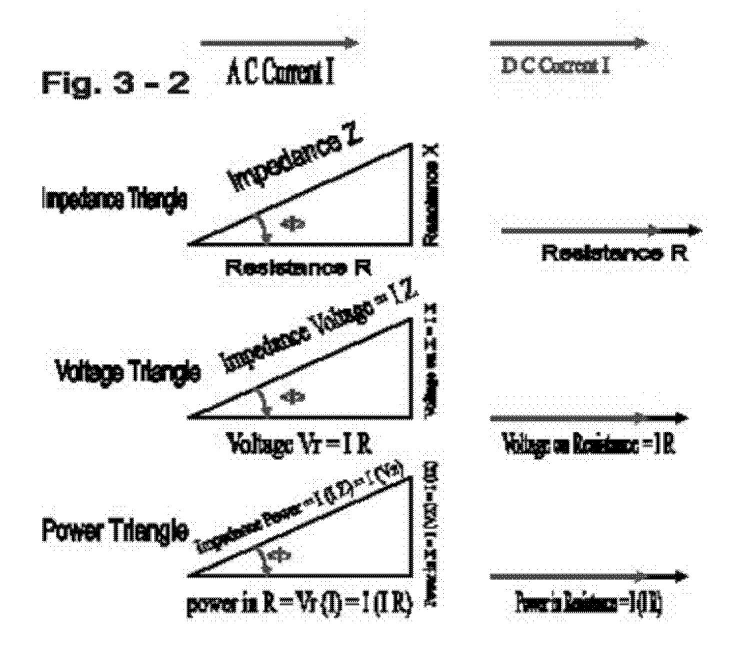
$$V = V_R + j V_X \quad (3-5)$$

So, this triangle is known as the voltage triangle.
Then, the three different major parameters (R, X, Z) must consume different values of power which can be expressed by

$$I(IZ) = I(I\ R) + I(\ jIX\ ) \qquad (3\text{-}6)$$

This expression may be mathematically formulated as

$$I^2\ Z = I^2\ R + jI^2\ X \qquad (3\text{-}7)$$



Again this may be redefined by

$$S = P + j\,Q \qquad (3\text{-}8)$$

Thus, the consumed power in the resistance is called as the resistive power or active power (P) while this power in reactance X is the Reactive power (Q). The final result of power is named as total power (S). Also, the units that used for each are different where watts active power. A new unit for reactive power known as volt ampere reactive (VAR) but it will be volt ampere (VA) for the total power. This is proved by the vector diagrams in Fig. 3 – 2 because they have various directions as vectors.

It is important to mention that the angle appeared in all of the triangles is defied as a ratio between both values of active power and reactive power so that it is normally expressed mathematically in the form:

$$\text{COS (f)} = \text{Active Power} / \text{Total Power} \qquad (3-9)$$

This angle would be variable (not the same) for different electric circuits except that :

$$\text{Active power} / \text{Reactive power} = \text{Constant} \qquad (3-10)$$

This condition may be in general for all three above triangles as

$$P / Q = V_X / V_R = X / R \qquad (3-11)$$

This ratio for the DC circuits is infinity because in DC circuits no reactive parts. Thus, the utilization of the input power to the circuit is the same of output power that means a 100 % utilization. This is the efficiency. Contrary for AC circuits this efficiency will not be 100 % except at the disappearance of the reactive parts in the circuits. This practically can not be reached. For this reason COS (ϕ) is called power factor which is equal to the efficiency.

2- Generating elements

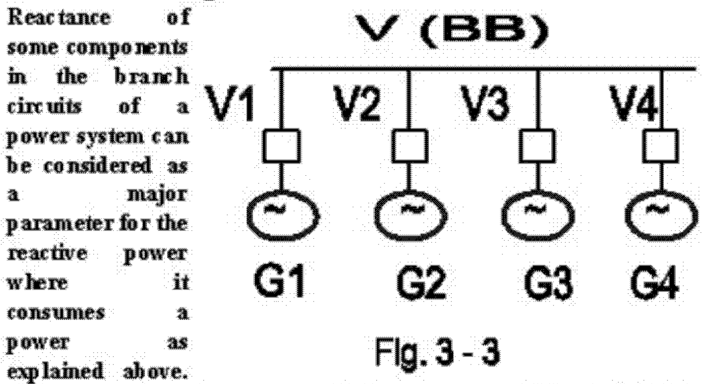


Fig. 3 - 3

Reactance of some components in the branch circuits of a power system can be considered as a major parameter for the reactive power where it consumes a power as explained above. This power is a loss power which goes away without utilization. Engineers always try to find any concepts in order to minimize such a loss. This is a purpose of engineering applications in order to covert it into a resistive (active) power. Whatever, windings are found in the most elements of the network such as alternators or transformers mainly.

Auxiliary reactance may be appeared with some other components such as Paterson coil or earthing coil, required at the neutral point of 3 phase generators. Also, it may be connected with different elements as short circuit limiters. This reactance may be required for the heavy loaded stations in order to reduce the short circuit level at the outage of a station. It is also, is mainly represented in the equivalent circuit of motors at load terminals. All of these and others may be the generators for the reactive power in a network. Reactive power will be increased with the rise of voltage level of a network due to the increase of corona effect as well as the appearance of stray currents which have an opposite action to that of reactors.

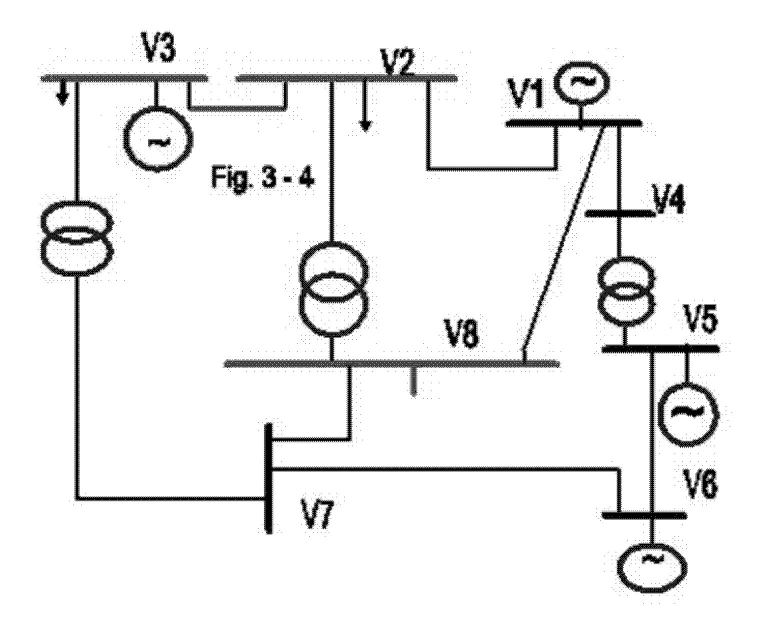
3 – 2: IMPORTANCE OF REACTIVE POWER

On contrary, the presence of reactive powers in an electric power system is not only a bad parameter but also it is a good factor. This may be explained and illustrated shortly next through the following items.

1- Power Loss

As it has been explained above reactive parameters are consuming a reactive power loss depending on the value of inductance. This yields the given above equation (3 – 11) where it likes the active power for resistances. This power loss cannot be considered as in algebra in value but it is a vector coordination style, so the mathematical formula expresses this meaning as:

$$\text{Total Power}^2 = \text{Reactive Power}^2 + \text{Active power}^2$$



or

$$(I^2 Z)^2 = (I^2 X)^2 + (I^2 R)^2 \qquad (3-12)$$

This may be simplified as

$$(S)^2 = (Q)^2 + (P)^2 \qquad (3-13)$$

In spite of the square sum relationship, the reactive power causes a large loss inside the network without any utilization. A management for these losses should be organized in order to get out the maximum possible active power. Engineering solutions may be useful since this engineering problem is a practical economic one in the field of electricity.

On the other side, the presence of reactive power in a power system represents a good benefit which may concluded in next points.

2- Phase Shift Characteristics

This title means that the reactance in a circuit will cause a deviation angle between currents passing through resistances and in reactance. This target may be appeared in the following categories:

a) The possibility of generation at different points of the network.

b) Control the process of power flow through connectors between stations and consumers at all user terminals.

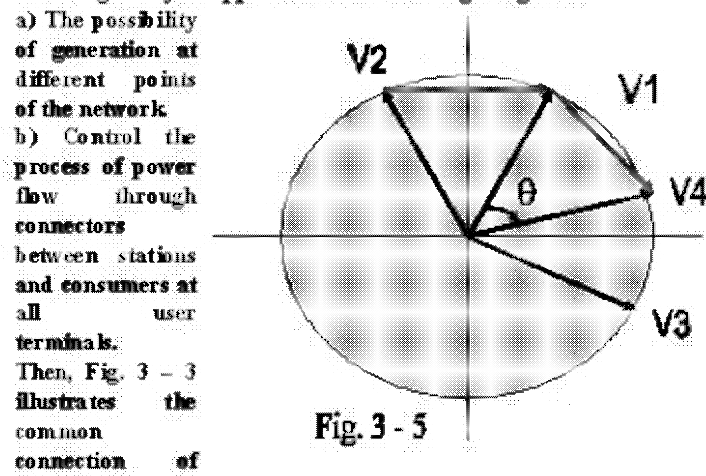


Fig. 3 - 5

Then, Fig. 3 – 3 illustrates the common connection of four alternators with the presence of these reactive parameters in the

operation performance of a power system. It is seen that four generators are connected to a specified single bus bar of voltage value of V while voltages of generators 1, 2, 3, and 4 are V1, V2, V3, and V4. Consequently, for a successively connection of these four generators with the same bus bar (BB) we must have the equality mathematical condition in a vector response:

$$V = V1 = V2 = V3 = V4 \qquad (3-14)$$

This proves that their voltage must be exactly the same, however, it is known as the synchronism condition. This is inside a power station for the same bus bar where the reactive value should realize this condition. This can be achieved through identical parameters for the four generators.

Contrary for the power system as a sample, which is given in Fig. 3 – 4 for example. Then, we must have different voltages that must be the same and identical such as:

$$V1 = V2 = V3 = V4 \qquad (3-15)$$

Now it is clear that the voltages are the same but they must permit a power flow as shown in figure. This is difficult because we have normally a standard value for voltage all as the same. For example the voltage may be 220 kV on all four bus bars which means that there is no voltage difference between them. Hence, there is no current flow so that we can keep the standard voltage value as 220 kV.

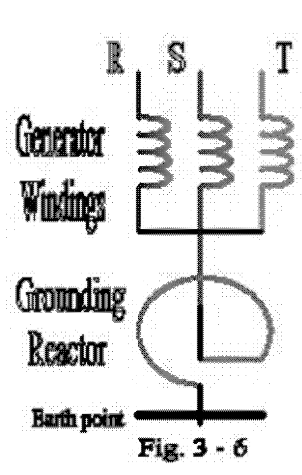
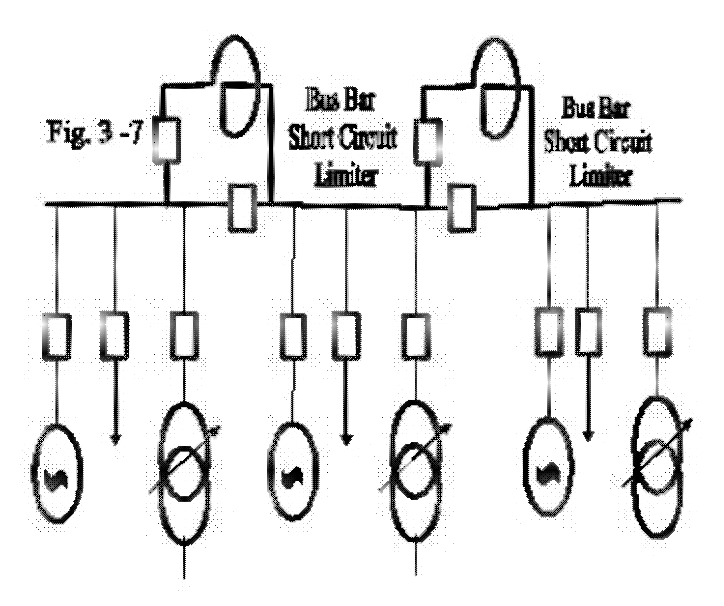


Fig. 3 - 6

Therefore, an angle ($\theta 1, \theta 2, \theta 3, ...$) can be generated between each and another for all of the values as given in Fig. 3 – 5.

$$V5 = V6 = V7 = V8 \qquad (3-16)$$



Similarly, these four voltages may be managed too, as the phase shift will produce a voltage difference of the value between the ends of two voltages. For example, their voltage level may be 66 kV. This concept is absent in the case of alternators on a bus bar, although there will be a flow for the power. It must flow from the common bus bar towards lines, then, to the adjacent stations according to the condition of operation requirements.

The phase shift here θ differs from the angle of power factor above ϕ because it is here between voltages at different bus bars in the united power system. So, its control will be easier and consequently, a current flow may realized in a power network even the voltage on all bus bars is the same in value.

3- Generator Grounding

The grounding phenomenon in a national network may be a necessity requirements for the normal operation of such networks under various cases of operation. However, it is usually needed for the alternators in power stations in spite of its defect for the differential protection on its windings. Also, the grounding through the Peterson coil is a practical application in this item. This means the use of reactance as a grounding element although it is preferred sometimes to eliminate the grounded points. This is done to cut the zero sequence circuits at short circuit conditions.
Since the use of reactive parts in a network solves some engineering problems, it is important to concentrate on the fact that: Reactive power in electric power networks is very important as well as the operation of networks cannot neglect this. The proposed grounding reactors at the neutral point of alternators is thus explained as it may be very clear with the drawn circuit in Fig. 3 - 6 where the electric connection in a 3 wire system is given. This reactor must be introduced inside the zero sequence current circuit for the calculation of short circuit currents during faults.

4- Short Circuit Limiters

The most common trouble in the operation of a network appears to be the cases of short circuits that the system may be subjected during this operation. The restrictions either administrative or engineering cannot cover or prevent the occurrence of either short circuits or even the abnormal conditions. It must be said that the presence of short circuit conditions during the operation of networks represents the most danger problem. This case of emergency may be eliminated or minimized as possible through the use of short circuit limiters. So, these limiters may be one of the circuit components such as

resistance or reactance. Since these components must be connected in series of the circuit, the use of resistance will have a negative effect. This is due to the power loss in it which is active power while the reactance consumes zero active power. Then, the use of reactors in series inside a power system would be preferred. However, the short circuit current limiters may be tailored in the form:

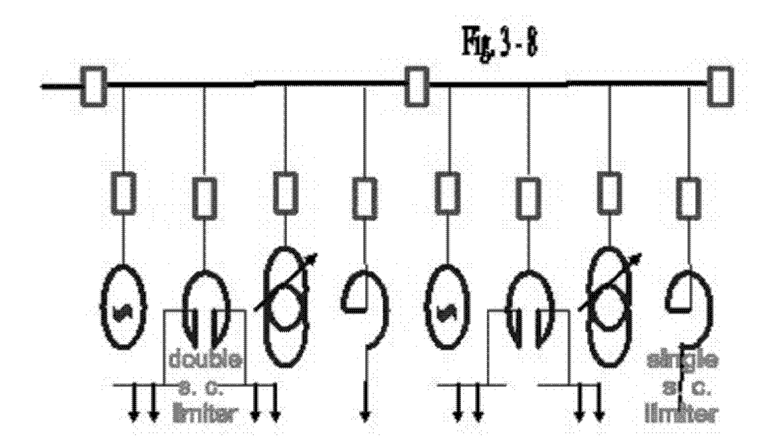


Fig. 3 - 8

a) Bus Bar short circuit limiter

This reactor used for this purpose is shown in the circuit delivered in Fig. 3 – 7 while it is used between sections of the bus bars. It limits the flow of current during short circuits.

b) Single short circuit limiter

It is a s. c. limiter for a certain load or some loads specified on a single bus bar for the distribution purpose. This is shown in Fig. 3 – 8 where a single reactor is inserted in the circuit in series.

c) Double short circuit limiter

With the two types of limiters as single or double limiters, Fig. 3 – 8

presents a scheme for a power station or a part of it where the short circuit limiters are used. It is seen that a limiter at the bi- section of a bus bar (Fig. 3 – 7) as well as a limiter at the feeder outage.

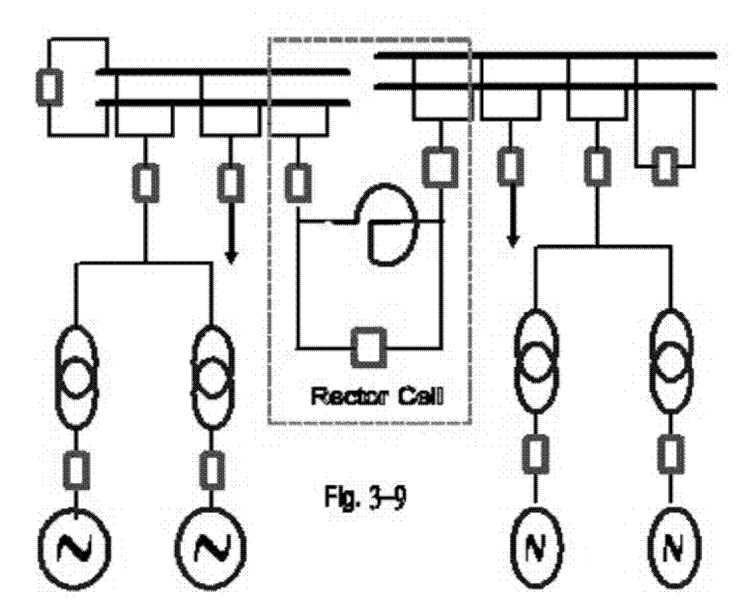


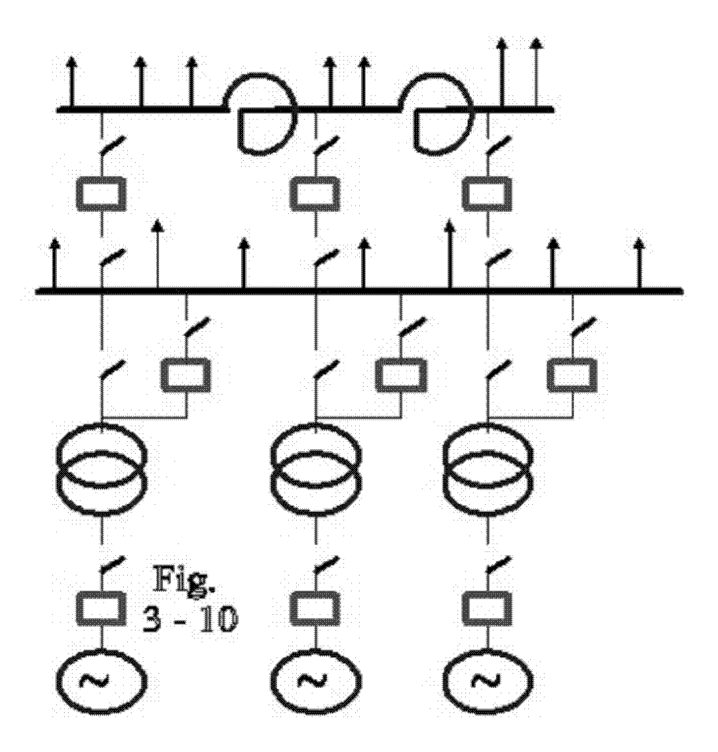
Fig. 3–9

It is given on this scheme also a single limiter reactor for feeder or bus bar section and also, a double short circuit limiter for feeders at the low voltage level. Thus, the role of reactive power is a major when it is difficult or even impossible to operate without the presence of reactive power.

3 - 3: INDUCTIVE PERFORMANCE

Since the bus bar can be considered as the main point in the scheme of a station, more details for this bus bar with reactors may be important. As it has been proofed before that a double or a triple BB

system will need the BC unit as a tool for the coupling between each two BB (main and spare).



Then, we repeat the same but with the sectionalization concept where a bus tie could be inserted in series between each two adjacent sections of a BB. There are many styles for the insertion of a reactor in a single line diagram. It may be required for many reasons such as reducing the short circuit current and sometimes for the control angle at a bus bar. Also, it can be used for an angle creation between

terminals of alternators connected to a bus bar.

1- Reactor Insertion

A short circuit limiter can be connected in series too. It is seen from Fig. 3 - 9 that bus tie operates for a double BB system since a reactor can be connected through any of both. Here the bus tie is doubled and became twice circuit breakers for the purpose of reliability. It is important to indicate that the inserted reactor will minimize or reduce the short circuit current during a fault. In the same time the reactor drop can be controlled in order to find the best operating condition for the network.

The given idea can be implemented as a reactor cell so that this rector can be connected during the high level of power. This will increase the equivalent reactance of a system at short circuit cases so that it would be a vital condition in some networks. This may have a good meaning with the great growth of power in power systems generally in the world.

On the other hand, this reactor can be taken out of operation by switching on the circuit breaker connected parallel with it.

2- Tie Reactor

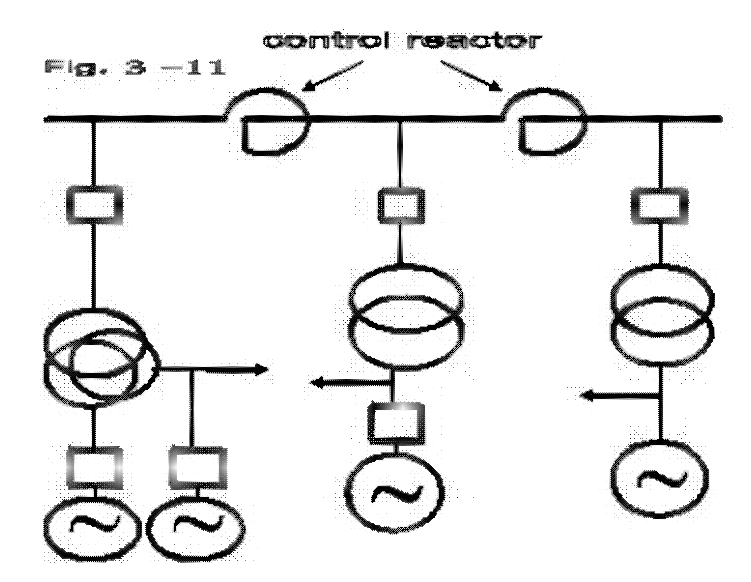
Hence, the reactor action can be increased to be a part of the bus bar as shown in Fig 3 – 10 where any switching elements can be added to the diagram shown. In such cases, the reactor will have a great roll to reduce the short current level at the bus bar so that the bus can face any future increase in the power level. This case will be of more importance with the distribution side of a power system although it will be of more and more importance with the new civilized area of population.

Whatever, the insertion of reactors in such a manner would act as a sectionalization style for the bus bar. This idea may go further to be a type of sectionalization for a station itself. This means that a part of section in a station works away from the other part. Thus, the reactor will divide the scheme into two independent parts with high level of reactance which means a low short circuit level. This style may be needed in future if the power level of a network became very

large.

3- Control Reactor

A reactor may be utilized in a power system in order to control the voltage angle between adjacent BB. This can be considered as one of the concept realizing the angle difference between two adjacent alternator. This permits the power flow from a bus to another without a change in the value of the nominal operating voltage level. The theoretical base has been explained above and consequently it can be applied in power stations. The circuit diagram for a power station when a voltage control may be used is drawn in Fig. 3 – 11. It presents the electric scheme in such cases although there are many other concepts applied for the same reason.



4 – Line Reactor

It is known that the greater power transmission needs a longer transmission line so that with EHV or UHV levels long length for transmission lines would be implemented. Thus, long lines at such levels of voltage generate a high capacitive power due to the presence of stray currents. This leads to an increase for the voltage at the terminals of a transmission line. This is known as Ferranti Effect that means a negative effect should be introduced in such long transmission lines. So, A reactor must be installed at the receiving end in order to compensate the capacitive power. Fig. 3 – 12 presents this condition where a reactor has been installed at the receiving end of the long UHV transmission line.

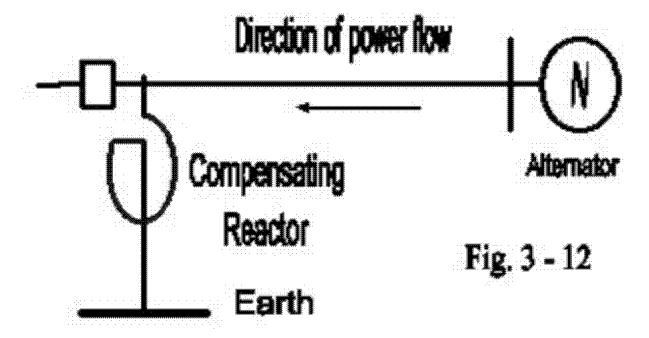


Fig. 3 - 12

3 - 4: CAPACITIVE PERFORMANCE

It should be mentioned that a balance for the reactive power presented in a power system represents the target of designers for any electric circuit as well as for such united electric networks. This importance will grow more with the increase of the demand of a network as a whole. Thus, power factor comes to the front of power flow and its control so that the use of condensers gives advantages as:

1- Parallel Condensers

Parallel condensers are widely used in the distribution systems so that an automation concept may be standardized for their applications either at a local individual sites or in the large power industrial locations. The automatic circuits mostly depend on thiryte switching base in order to cover the smooth effect against the reactive power required. This process must include some factors:

a) Avoidance of the over voltage appearance at light loads.

This may be generated due to the presence of condensers in the electric circuit for the full load operation. This phenomenon occurs with the excess of capacitive power at a decreased load. Thus, automatic or even manual control must be considered.

b) Avoidance of the presence of advanced power factor operation.

This phenomenon is not desired because the loss will be increased with instable operation of generating elements in the network as a whole. This is a danger condition because it generates an extra over voltages during switching processes so that their values may exceed that of lightning strokes in UHV power system (Fig. 3 – 13).

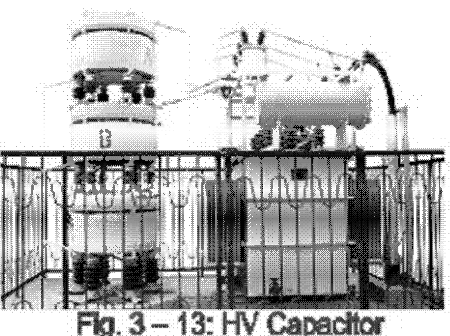


Fig. 3 – 13: HV Capacitor

This safety of a power system operation either at distribution or transmission systems can be achieved by:

i - Circuit breakers with definite time according to the performance of the load curves of the site or bus bar point.

ii - Circuit breakers with voltage sensors at the bus of power factor

improvement. This sensor must lead to trip the breaker or breakers if the measured voltage increased above a specified nominal value.
iii - Circuit breakers with current sensors – if it is difficult to work with voltage – plus a timer when a ratio between maximum and minimum operating currents exceeds 3 times. This case is suitable for high starting currents as motors and transformers.
iv - Circuit breakers with reactive power measurement. It is suitable for the user terminals.
It is remarkable that the unit required for switching off or even on a bank of condensers would be arranged in tapped system (sequential style) to treat the consumption of reactive power at the point of measurement.

2- Series Condensers

Series capacitances look like the parallel Condensers where the difference between both types comes in the style of connection. The parallel condenser generates a reactive power in the power system while the series condenser consumes this power (Fig. 3 - 14).

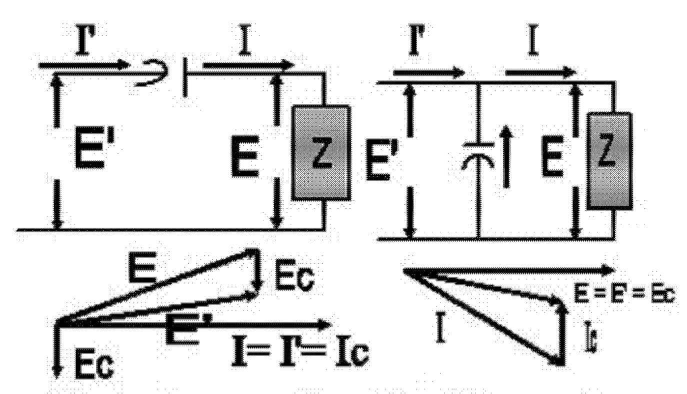


Fig. 3 - 14 : The Reactive Effect in a circuit

It is very important to indicate that in this book we can write or analyze any theoretical item but only the basic fundamentals required for coupling with the subject of station design. Thus, all above or before or even next theoretical subject may be treated on the same base of analysis.
Now, it is needed to say that the location of condenser in a power system as well as the shape of unit or units used depends to a great extend on the performance of daily load curves.
Whatever. for more accurate design a fundamental information may be necessary as:

a) A complete electric scheme with all nominal parameters for all contents.
b) Maximum and minimum values of power.
c) Maximum and minimum forecasting values of power factor.
d) Maximum and minimum forecasting values of load consumption as well their performance at both steady state operation and transient conditions.
e) The determined target for the reactive power compensation.
f) Air temperature.

3- Compensation

Since Condensers in general play a great roll in the process of control of lines and feeders all levels of voltage (0.4 – 750 kV), an accurate automatic control may be specified. This may be achieved in two main axes:

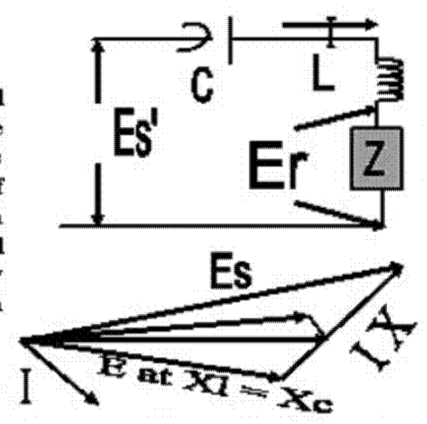


Fig. 3 – 15: Comensation with rective power

I - Voltage Control

This method includes:

a) The use of tapped transformers at both ends of a line.

b) Installation of Parallel reactors at the end of UHV long transmission lines. This is important with light loads on long lines.
c) Connection of parallel condensers with lines during high loading or when it is loading at a low power factor.
d) Series condensers must be connected with lines when the loading is nonlinear.
e) Accurate and smooth voltage control may be realized through power compensators.
f) Exact automatic control for the exciters and voltage regulators in power stations..

II- Power Control

Since both voltage and power are related together, a change in one of them leads to a variation in the second in an indirect way.

1- Voltage control by controlling the value of power flow through a line.

Control of active power flow may be reached by the angle between both voltages at the ends of a line.

2- Power flow control may be achieved by injection of a line by the required power through reactors and condensers which connected to.

They may be series or parallel connected with the equivalent characteristics of the circuit given in Fig. 3 – 15. This, also, may be more real able by the synchronous condensers on UHV lines.
Series condensers gives the difference in inductive powers of a line and a condenser.
Whatever, reactors reduce the short circuit current although series condensers lead to raise their values to great limits. Whenever, switching processes of condensers in a circuit generates high values of voltages and, consequently, the currents so that series condensers need a special care in connection with a power system. Fig. 3 – 15 presents one concepts of the series condenser connection.

3- A damping circuit consisting of reactor and resistance is necessary at the moment of switching condenser banks either in the case of ON or that of OFF.

For UHV transmission lines the length for lines may be increased to a value that the voltage operation becomes unstable so that a sectionalization concept could be the solution. Then, with this base we can cut a long transmission line into two or three or even four section in order to treat each of them according to the practical condition.

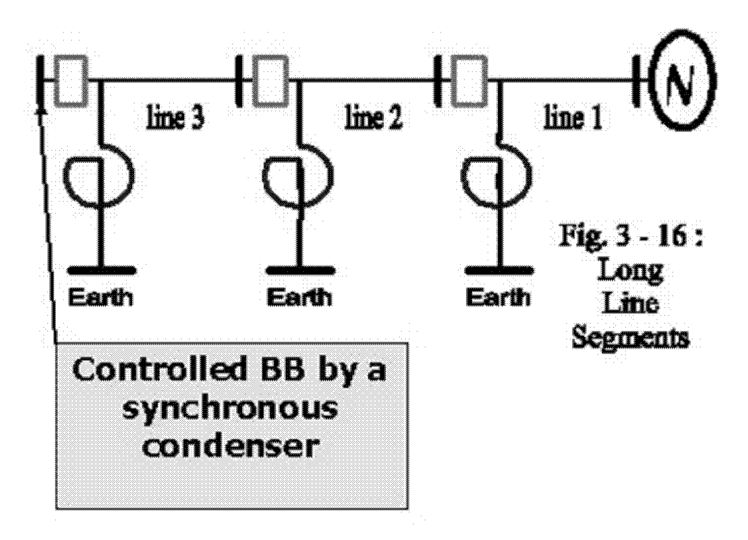
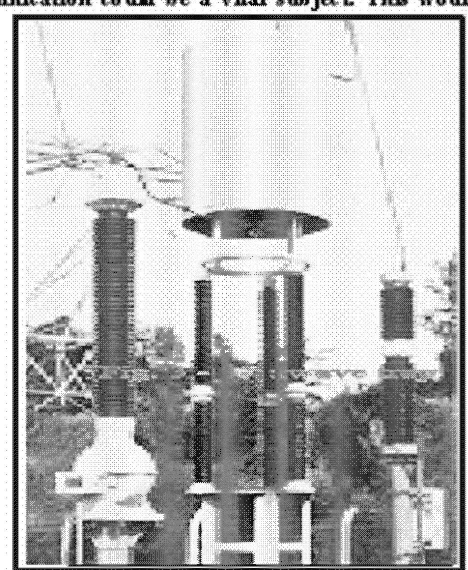


Fig. 3 - 16 : Long Line Segments

This is explained in Fig. 3 – 16 where a very long transmission line is cut into three equal parts. The first part needs a reactor on its end to cover the Ferranti Effect during the steady state condition but the second will need more powerful reactor to cover some of the first in a special situation. Then the last part will need the same although it needs more accurate control for the voltage at the receiving end bus bar. This means that a synchronous condenser should be inserted in the circuit at this final.

4- Coupling

However, a lot of stations and connectors form a power system so that a mutual communication could be a vital subject. This would required to cover not only the faulty conditions but also the steady state operation. So, a supervising control will be needed and then a mutual coupling between the major site and all others must be created. Hence, a dispatching center will be the aim while also, coupling between stations together



as well as with other places. Therefore, an automatic coupling should be found out. This may be the utilization of the present connection such as wires of the lines to carry the signals of communications. So, a HF or EHF would be the solution to realize this coupling. Since the wires at a power frequency 50 or 60 Hz a HF away from power frequency to be loaded on the same wires of HV but at a very low voltage.

This process can be implemented through electric filters which is titled as "Wave Trap" as shown in Fig. 3 - 17. From this picture it is seen that the wave traps would be installed at the ends of all transmission lines to connect between these ends. This style can be extended to cover all stations and dispatching centers. It may reach to other important places such as centers of leaders. Also, this wave trap has been modified to be connected to all points of the system

operation and supervision through a LAN computer system. It can be extended to utilize it as a concept with accurate operations in the control and supervision of the electric power system as a whole.

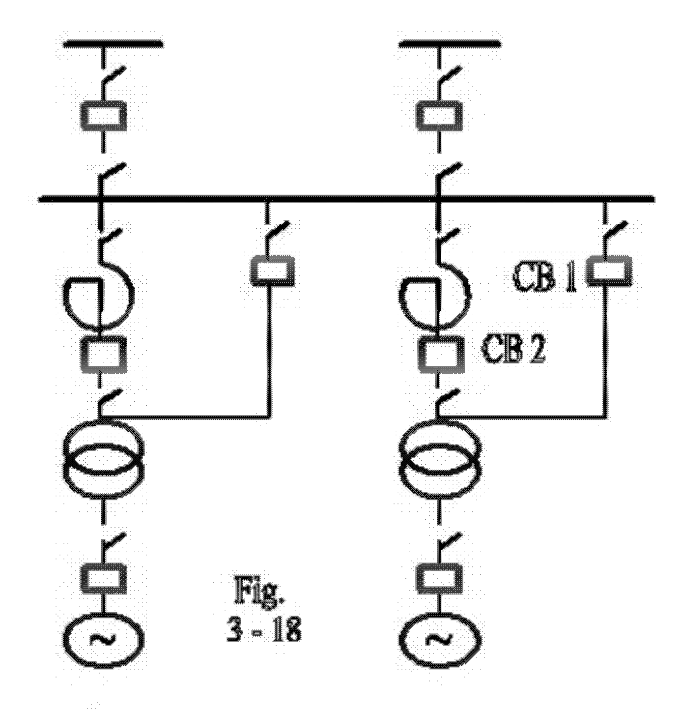


Fig. 3 - 18

5- Applications

There are a lot of <u>Practical Schemes</u> which may be defined as standard schemes. The most common systems individually can be presented for simplification as:

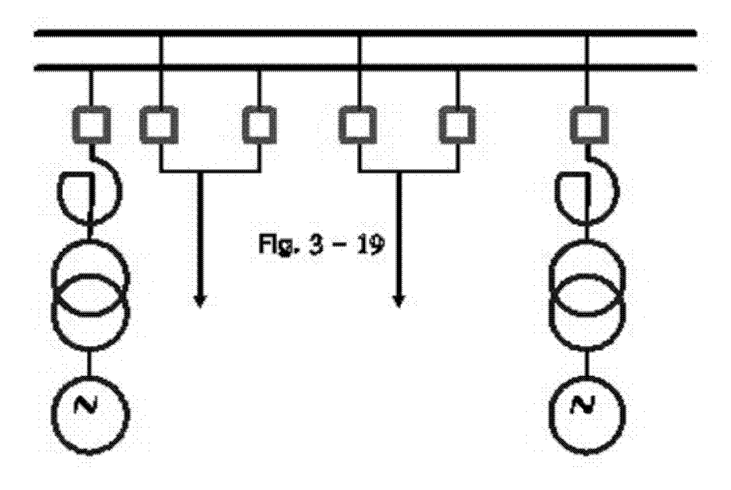
a) Automatic Short Circuit Limiter

This style exactly means that during a faulty time and at the moment of starting (during) a fault (Fig. 3 – 18), the circuit breaker 1 can be

instantaneously opened. This leads to carry currents during short circuit through the other branch containing a reactor. So, the short circuit reactance will increased which means a reduction of the existing current. Then the CB 2 can be opened to cut the circuit in order to isolate the faulty part in the network.

b) Direct Short Circuit Limiter

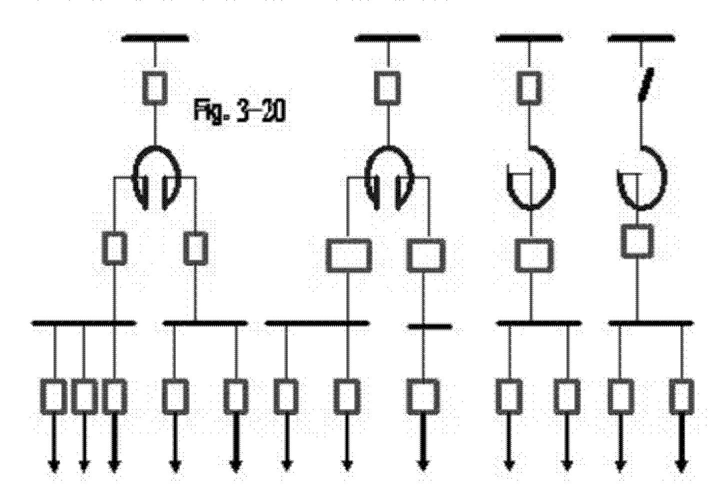
Reactor limiter has been drawn in the electric circuit of Fig. 3 – 19 where a generator current has been limited through the reactor element. It is connect to a certain bus as there are two alternators with two bus. Each bus takes the supply from one generator only but this condition of operation can be improved with multi alternator system. This leads to a more reliable system as well as the generation would be raised.


Fig. 3 – 19

c) Load Short Circuit Limiter

Load reactor limiter is connected normally to the load in series in order to reduce the short circuit current during faults. This is simply

given in Fig. 3 – 20 where a high utilization for a reactor in shown because one reactor double winding system is connected to the power system at load terminal. This minimize the area occupation as well as the number of reactors used.
In the scheme of Fig. 3 -20 both types of reactor elements are shown as the single winding reactor limiter as well as the double winding reactor limiter. Both of them do the same and reduce the short circuit current during faults.
Finally, it is a vital point to indicate that the reactive power in general represents a lung for the power system because it helps us to control the voltage at all points of the system at a specified value. This makes the use of electricity as easy as possible whenever all applications tends to use electric source of energy. This is a good factor since the production of all equipment and instruments will save money. Away from economic point of view this concentration in electricity use other types of energy may be ignored or at least be late in use. So, an optimal engineering view should be created in order to make a balance between both conditions.


Fig. 3-20

Chapter IV

SWITCHING ELEMENTS

The subject of design and its explanation makes the concept more difficult due to the needed experience from practice and theory. The above chapters deal with the items of theory and basics where a lot of problem must be already achieved.

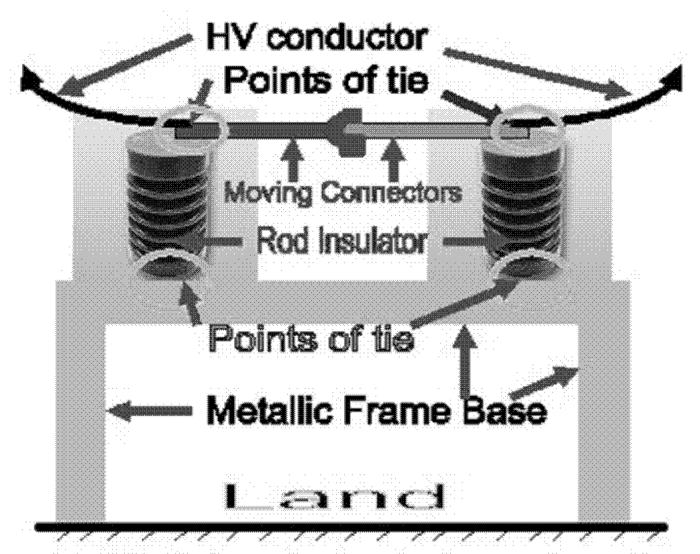


Fig. 4- 1 : Main construction of a disconnecting switch

Therefore, some helping tools will be aiding for the idea of the book so that some practical examples would be presented with a comment to make the subject easier. The present chapter deals with this item

to cover the individual concept for the explaining. It is important to be marked that some pictures in this chapter and others are scanned from the references listed at the end of the book.

4 - 1: ISOLATING LINKS

Isolating links as a shape are different but the most wide known types may be included here for illustration. This means that the presented diagrams or sections or even items are a sample of the subject as a whole where we put the most used types for explanation. Also, various types may be studied on the bases of the given idea so that our samples can be used as a guide for a certain subject. The present chapter concerned with the explained already items in the previous chapters and then consequently, this may lead us to be sure to understand all samples which would be related with.

I- Shapes

The most common shape of high voltage and ultra-high voltage level isolating links is shown in Fig 4 – 1. It explains the components of a link while the other parts of a link would be given later in the present chapter. Also, both elevation and plan for a disconnecting switch will be given later in the chapter of lay out of stations so that other types would be understand without any

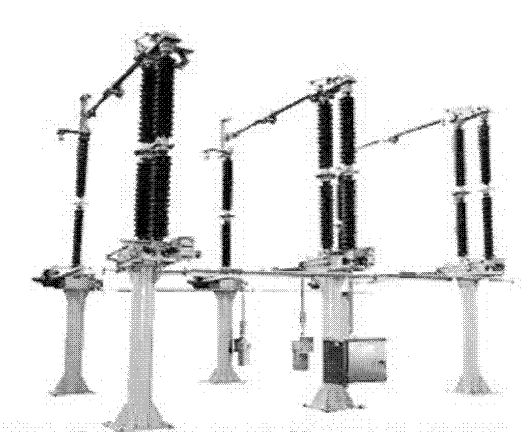


Fig. 4 -2 : The arrangement of 3 phase isolating link

difficulty or effort. The insulating support must be good tied mechanically at its base with the metallic frame as well as at the top where the points of connections with the HV conductors. There are a high mechanical force at each point of the insulator base during the movement of the arms of the link while the tie should be good at the top where the high current carrying capacity at the time of operation of the circuit. A general shape for an isolating link is presented in Fig 4 – 2 where the three phase are located according to a specified symmetrical spacing. It depending on the voltage level of the isolating link.

On the other hand the moving contacts must be classified for moving process as it is expressed into two main types.

II- Horizontal moving arms

It is said before about the variety in the direction of motion of the arms of the isolating links specially with the UHV level where the width of a cell will be greatly increased up to a value may be incredible. So, such horizontal isolating switches will be for the level of voltage up to 330 or sometimes 400 kV. Then, a movement of a HV isolating link (Out Door) could be drawn in Fig. 4 - 3 as an example for other levels of voltages. The general allocation for such isolating links may be remarked as

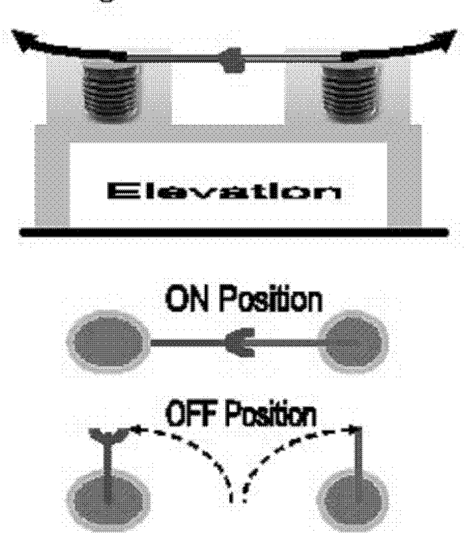


Fig. 4 - 3 : Positions of a disconnecting switch

And also,

New outer distance to earthed points = E + A / 4   (4–3)

This is an economic solution for the design of stations because the other elements are internally installed such as circuit breakers where the moving contacts are inside the arcing chamber without any effect on the outside dimensions.
This idea cannot be repeated or tailored to be sectionalized more and more because of the difficulty of mechanism required for such concept. Whatever, the main application can be easily used in the HV level but this tendency may be impracticable with the UHV levels. Then another base would be considered to overcome this problem.

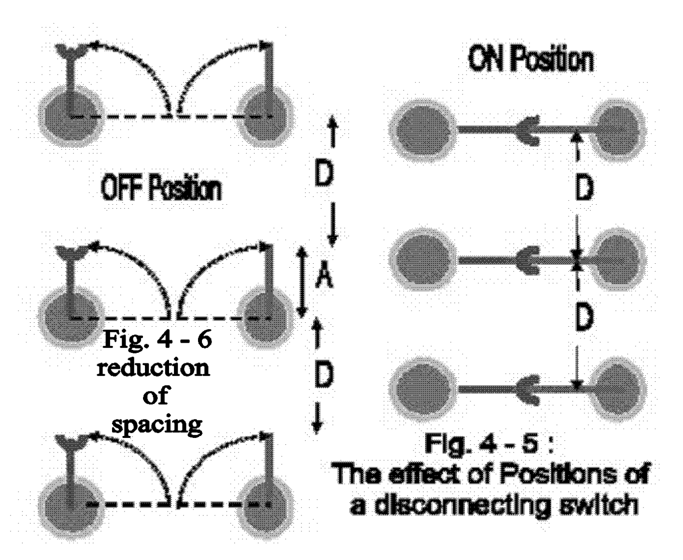


Fig. 4 - 6 reduction of spacing

Fig. 4 - 5 : The effect of Positions of a disconnecting switch

presented in Fig. 4 – 4 where a harmony style is shown.
Both positions of a disconnecting switch can be shown in Fig 4 – 5 while the difference between ON and OFF positions is reflected on the distance between life wires. This will affect also the distance between the outer phases with the nearest earthed metal since the life arms will move towards the trusses or any metallic stands in the place. If we assumed that this distance may be E, then the new one should be longer. This may be explained in a mathematical formula that the spacing between phases is D while the arm of an isolating link will be A. Then, the spacing between phases at the ON position can be simply D. Contrary, this cannot be permitted for the OFF position where the distance between the life conductor (one of the arms) and others will be increased than the basic spacing D. It may be expressed as:

$$\text{New outer distance to earthed points} = E + A$$

$$\text{New spacing} = D + A \qquad (4-1)$$

This case of operation may generate an engineering solution in order to minimize this total new spacing. This can be realized if the added distance to the spacing could be reduced. Thus, a new shape for an isolating link would be produced as shown in Fig 4 – 6. where the arm of the disconnecting switch is divided into two parts. This will give us a length for the deduced new arm of a half from the original value. So, a good tendency is applied.

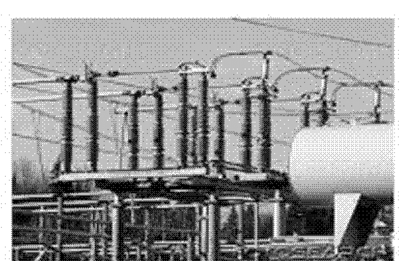


Fig. 4 - 4 : Outdoor AC High Voltage Disconnecter

Therefore, the new spacing and distances become

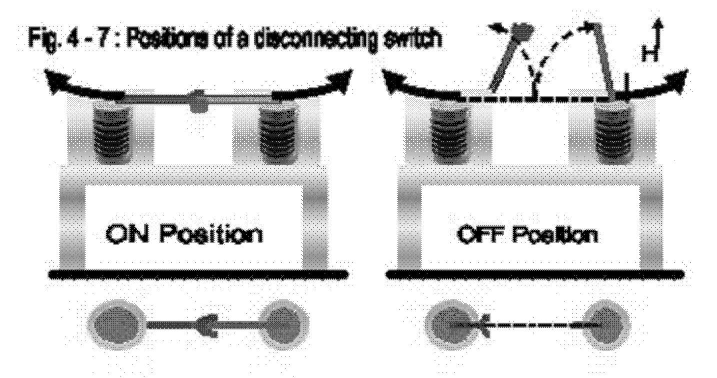
$$\text{New spacing} = D + A / 2 \qquad (4-2)$$

III - Vertical moving arms

As the nominal operating voltage directs towards the higher, the insulation coordination will sharply raised. The UHV levels leads to a new idea about the direction of movement of the arms to be in the vertical direction. Thus, the spacing between phases and consequentially, width of the cells will be decreased with this new idea. Fig. 4 - 2 illustrates an isolating link for the 400 kV level while for the level of 750 kV the isolating link may be drawn as in Fig. 4 - 7. Otherwise, the 750 kV isolating link has arms both to be rotated in a wide angle rang in order to minimize the distances between conductors in the direction of the vertical axis. This can be shown from the figure.

This condition represents a saving spacing as it will be the same as the disconnecting links as in the case "OFF" as in the condition "ON". Therefore, a good advance has been reached specially in the voltage level of 500 kV and above while one general shape for this type at 500 kV is given in Fig. 4 - 8.

Fig. 4 - 7 : Positions of a disconnecting switch



If the horizontal type is used, the actual spacing will be greatly raised to an impractical value. Thus, it solved the problem of spacing in spite of the direction of moving connectors. In such cases, another problem would be appeared where the height of connector will cause a HV points at its end above. So, the distance between this point and

any other conductor will be raised greatly so that the idea of sectionalization would be solution. This may be shown in Fig. 4 – 9.

IV- Earthing Rods

The earthing presence in the site is an important and vital item to cover the protection against danger either with the respect to persons or the equipment. Then, the earthing rods are a good tool to be attached with.

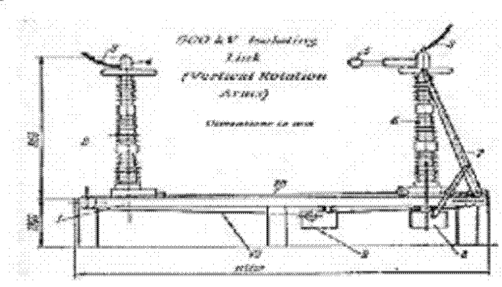


Fig. 4 – 8: 500 kV Isolating Link

This tool is given in Fig. 4 - 10, which indicate the operating direction of such rod to make sure that the arm metal can be in a good contact to earth. Accordingly, as there are two sides for the isolating links where it is possible to be one side under tension even the circuit is idle.

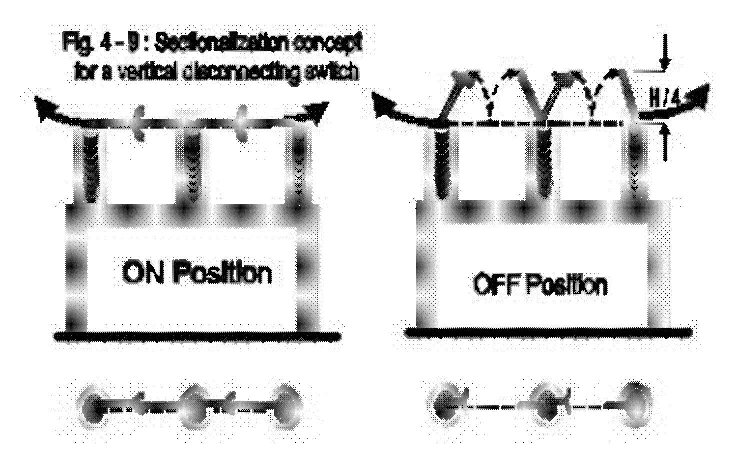


Fig. 4 - 9 : Sectionalization concept for a vertical disconnecting switch

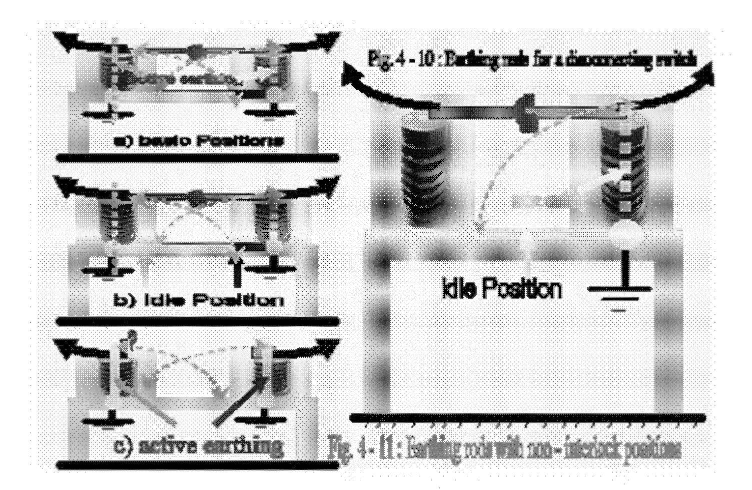


Fig. 4 - 10 : Earthing rods for a disconnecting switch

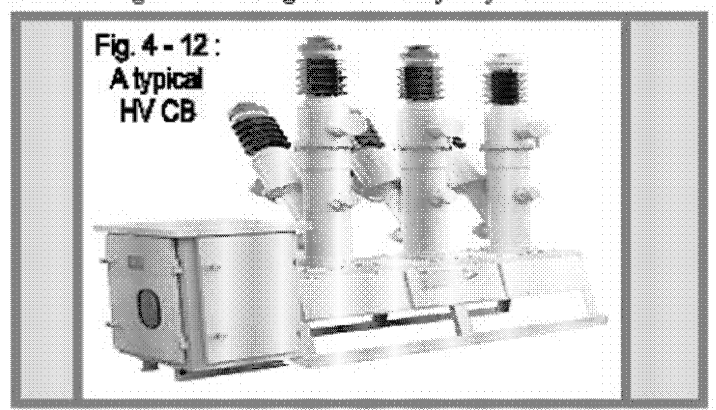
Fig. 4 - 11 : Earthing rods with non - interlock positions

Consequently, earthing rods should be installed for both sides as shown in Fig. 4 – 11 (a) while the two conditions for the operation of a link would be illustrated on Fig. 11 (b) for the case of idle earthing (operating condition) and the earthing active case (when the circuit without any tension on both sides of the disconnecting switch.
There are a third one when the isolating link out of work but one side is energized from another circuit so that both independent earthing rods must be considered. Also, an interlock concept should be inserted to prevent any wrong operating step during the sequence of closing or opening a circuit in the station.

4 - 2: CIRCUIT BREAKERS

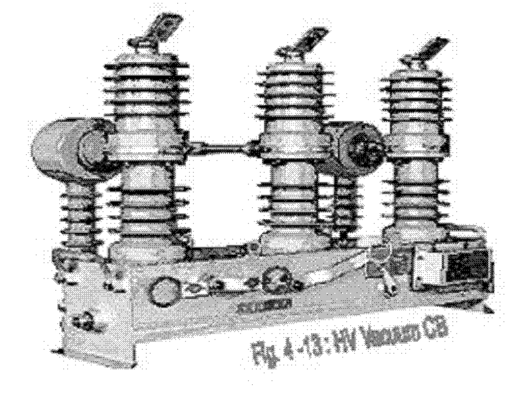
Since the circuit carrying capacity works and needs to be switched off, a special tool for this purpose would be handled. This may be used through the known tool as circuit breaker and it may be increased capacity with the rise of operating voltage. Fig 4 – 12 presents one of the small HV circuit breaker in spite of larger breakers will be required for the higher voltage.

There are many types of the circuit breaker either for the service level of voltage or for the higher where they may be classified as:



1- Vacuum Circuit Breakers

The principle of current cutting, the arc induced during the breaking of the circuit, is the absent of air (mainly Oxygen). It has internally two types (vertical or horizontal installed) where vertical shape is shown in Fig. 4 – 13. This style permits a large capacity relative to the volume of the body.



It is seen that the case is hardly sealed in order to keep the evacuation property inside the vessels.

A high value can be remarked as the size of a vacuum circuit breaker should be small. At lower voltage a vacuum circuit breaker has been used widely specially in child schools where the compact close style is implemented. It should be said that with the vacuum circuit breakers either low or high voltage level a continuous evacuation must be possible because such circuit breakers could not work when just the vacuum pressure has been lost.

2- Gas Circuit Breakers

The most common gas used in circuit breakers is SF6 which has a high performance with sparking characteristics. Then, its application in such fields takes an important view so that it may be the only gas used in arcing chambers of circuit breakers. One of such circuit breakers is shown in Fig. 4 – 14 where it occupies a small relative place to the traditional air blast circuit breakers. Also, some of the fundamental specifications for such types of circuit breakers had been listed in Table 4 – 1 where the distribution voltages of 6 - 12 kV are considered.

Table 4 – 1 : General specifications for SF6 LV circuit breakers

Parameter	Value
Rated voltage, kV	6 / 12
Rated normal current , kA	1600 / 3200
Frequency, Hz Breaking capacity, kA Peak current, kA	50 (60) 40 / 32 128
Maximum thermal stability current (3 s)	40 kA
Total breaking time, s Total closing time, s	0.055 0.075
Drive type (modifications are possible)	spring type
Dimensions, mm Weight, kg Start of manufacture	740 × 800 × 1200 160 - 270 1999
price, ($) at the end of 20th Century	5000 - 8000

3- Air Circuit Breakers

This circuit breaker is widely used specially with HV level and above since its price is low with respect to other types for the same rapture capacity and quality. It does not need for vacuum pump or a special gas to be increased when required. It is also simple relative to the others although it takes a large place on the land comparing to others. Whatever, it needs only the air (simple air) in spite of its usual presence in every where.

4- Movable Circuit Breakers
(With-draw able Type)

This type of circuit breakers is suitable for all types of stations while it is practicable for the low levels of voltages. It gives more safety operation inside electric stations in general. Consequently, it appears to be an important tool inside the control room as well as the low voltage switch boards where the service feeders must be fed. Thus, we can see one small circuit breaker of movable body which must be withdraw out from its place of connection. This may be given for example in a simple type of movable circuit breakers as in Fig. 4 15.

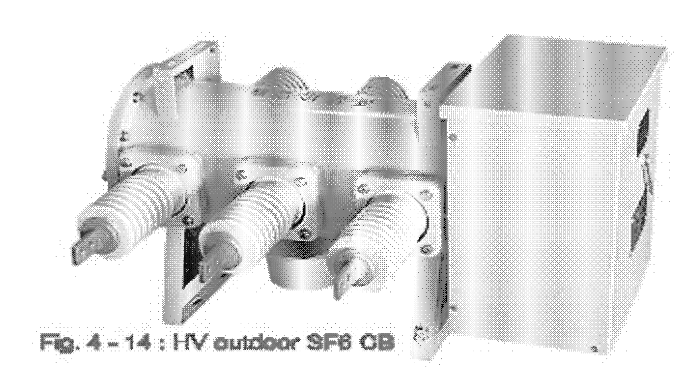


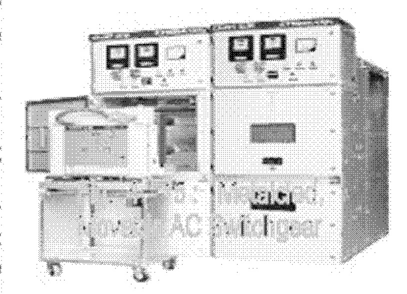
Fig. 4 – 14 : HV outdoor SF6 CB

5- Thermal Circuit Breaker

These breakers vary in a wide range but they are a major tool in both distribution and utilization level of voltages. They contain many different styles but the main general types can be tailored as:

a) Bimetal Switches

It depends on the over loading concept which cause a raise in the temperature. This breaker (switch) can be implemented with circuits of machines that generate a heat energy such as motors as well as the conditioning fields and freezing stations. It works normally (sensitive) with short circuit currents as its simple construction has been given in Fig. 4 - 16. This concerned to a different expansion between the two metals so that a connection for cut out the circuit would be appeared and activated.



b) Electronic Thermometer

It is used for controlling the temperature at a site or machine or a material where it may be presented into:

i- Positive Temperature Coefficient (PTC)

It is used usually with motors where the resistance is increasing with the increase of temperature. This controls the maximum temperature where it directly open the circuit. Then, if the temperature is returned to the maximum value and less it must connect the circuit automatically through the thermometer.

ii- Negative Temperature Coefficient (NTC)

It is a thermometer normally installed inside a motor. Its resistance is decreasing with the temperature increase, and then, the current

passes in it causing a rise of the temperature. Since the temperature become high it would operate and switch off the circuit.

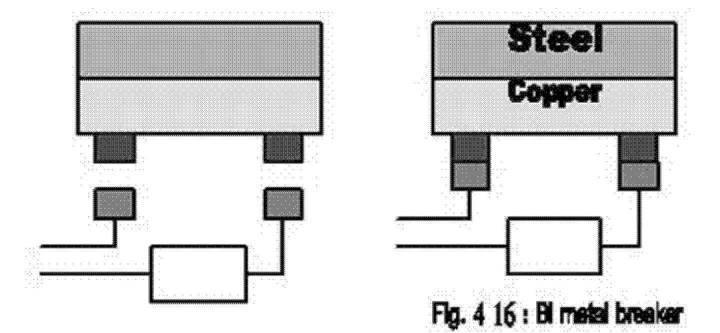


Fig. 4 16 : Bi metal breaker

c) Internal Overload (Overheating)

It is a simple protection device against heat excess where it can be useful for closed types of motors as in the cooling and freezing circuits. It is mostly activated at 52°C and tripping the circuit at 90 – 120 ° C although it can reconnect it directly if the temperature is reached the value of about 70°C.

d) Magnetic Solenoid

It represents a type of protection through an energized coil on the basis of induced magnetic field.

6- Miniature Switches

These switches pull the system of cutting out the currents in electric circuits in advance for a long distance because this type had overcome the disadvantages of fuses. They are spread quickly and covered all levels of utilization on distribution networks. A specified advantage includes with the long Electrical life which appears to be more than 6000 operations while the Mechanicall life is more than that of electrical life (more than 20000 operations).

Some of these types are shown in Fig. 4 – 17 while the most important general specifications are listed in Table 4 – 2.

They may be tailored into:

Table 4 – 2 : General specifications for Miniature circuit breakers

Rated current, A	No. of poles	Rated nominal voltage, V	Rated rapture capacity	
			Value, A	Power factor
1, 2, 4, 6, 10, 16, 20, 25, 32, 40	1, 2, 3, 4	240 - 400	6000 - 4000	0.65 – 0.7 – 0.8
50, 60, 63			4500 - 4000	0.7 – 0.8

a) Single pole switch

It is suitable for domestic applications as well as others and so it is characterized by the AC voltage nominal as 110, 240 or 420 V. The range of rated currents has a wide band starting from small currents of 1 A with increased steps up to 80 A.

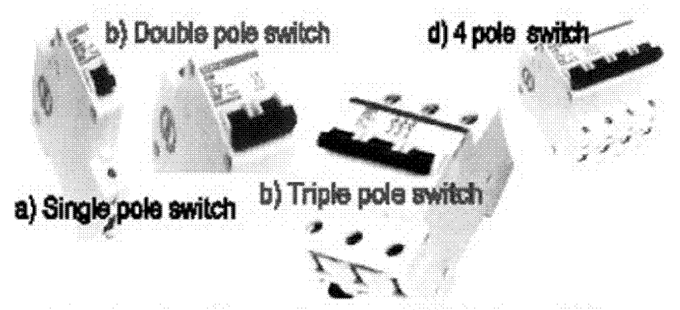


Fig. 4 - 17 : Some types of Miniature CB

b) Double pole switch

Since the switch contains 2 poles, it can be used to supply two single phase circuits or to supply a load of double phase.

c) Triple pole switch

It is mainly suitable for the three phase circuits although it can be used for single phase systems each pole for each individual load.

d) Multi pole switch

It is a general shape for the utilization either for three phase applications or multi-loads of single phase supply. The tripping performance of such switches is given in Fig. 4 – 18 where the sharp timing is clear during the operation of clearing a fault. Thus, it is successfully working in all types of electric circuits.

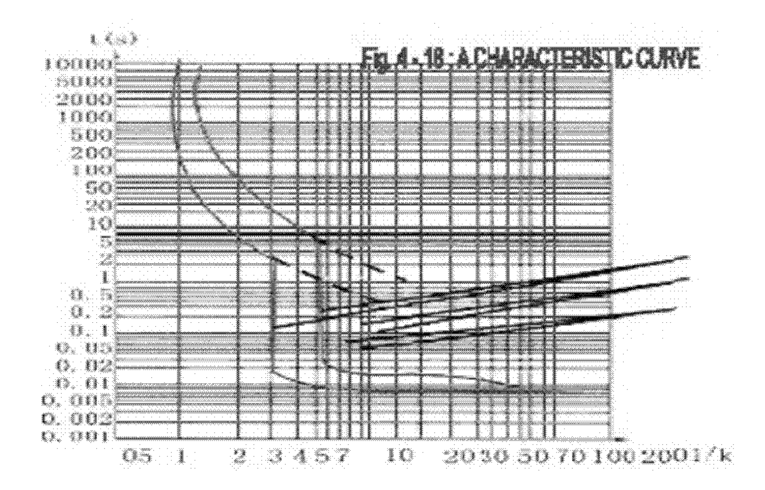


Fig. 4 - 18 : A CHARACTERISTIC CURVE

7- Screw Breakers

It is a new shape for the above types of circuit breakers where it is installed like the screw lamp in the circuit. This means that both terminals of this circuit breaker is an internal point inside the envelop. Then it permits a lower level of currents which may reach 30 or 32 A instead of the high value of 63 A.

All above mentioned types are in use inside the installations of a station at the distribution level. This means for the loads internally in the electric station of for the outside services.

8- Earth Leakage Circuit Breakers

Since the danger factor is high inside all electric stations, it will be important to protect the labor as well as the equipment. Then, the earth leakage protection can protect the human against the high values of touch voltage. This voltage may reach a dead value so that a certain limit for the stray current to earth can be useful. This leakage breaker is similar exactly for the Miniature breakers as shown in Fig. 4 – 17 and its general characteristics are illustrated in Table 4 – 3.

Also, a residual current Circuit Breakers may be another application for such style of protection where its rated currents begin at 16 with steps up to 100 A for double pole style at nominal AC voltage of 240 V (or 4 poles 420 V). This condition of working have two limits (Maximum and Minimum) for the voltage operation as 265 and 102.]

All types of circuit breakers have many advantages that may be abstracted as:

Table 4 – 3 : General approximate specifications of earth leakage breakers

Rated current, A	Leakage acting current, mA	Rated voltage, V	Rated current, A	Leakage acting current, mA	Rated voltage, V
16	10	240 / 220	25	30	240 / 415
25			32	100	
32	30		40		
40	100	220 /	63	300	
63	300	380			

a) Easy open or close any part in the power system without any effect on the other parts.

b) Releasing any thermal effect that can be remarked at any equipment working in the network by isolating a high temperature device out of the system.

c) Facility and simplicity of maintenance for each part of the system.

d) Control of short circuit effects.

e) Protection of each part in the network.

f) Touch voltage protection through Earth Leakage Current settings.

This voltage may be appeared due to:

i- Unbalance of the system

ii- A connection between phase wire and the device body.

iii- Bad local eathing.

iv- Reduction in the insulation level.

Rapture capacity I_{sc} may be calculated through the branch resistance R_b as well as the branch reactance X_b approximately, according to the general formula:

$$I_{sc} = [V/(3)^{1/2}]/(\Sigma R_b^2 + \Sigma X_b^2)^{1/2} \text{ kA} \qquad (4-3)$$

9- Fuses

Fuses are the likeable tool for protection in the field of workshops due to its simplicity with reactions at faults. All old workers in the field prefer it specially with motor branch circuits. The cooked prepared tables (such as that in Table 4 – 4 for example) for its applications with motors support workers to stay for a while away from the above Miniature type.

Table 4 – 4 : Standard fuses for motors

Power (HP)	240 V	120 V	Power (HP)	240 V	120 V
¼	1.5	2.9	¾	3.7	7.4
1/3	1.8	3.6	1	4.7	9.4
½	2.6	5.2	1.5	6.6	13.2

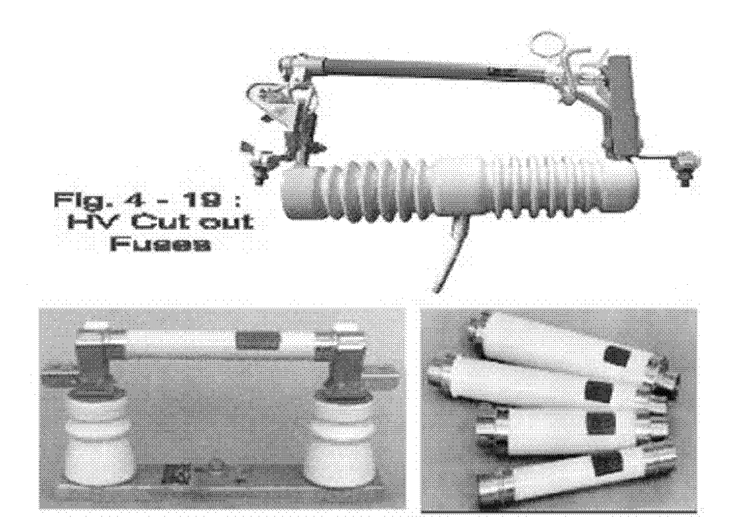
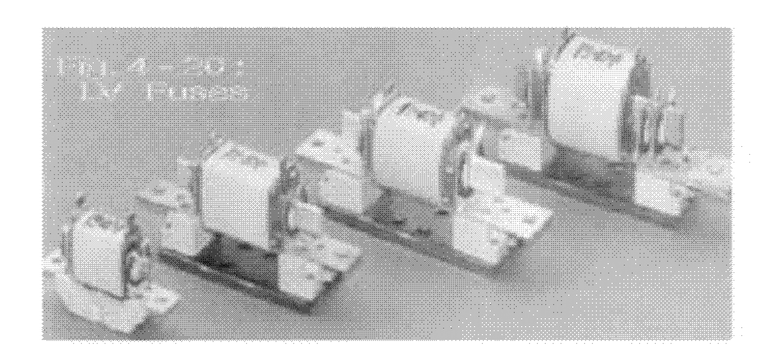


Fig. 4 - 19 : HV Cut out Fuses

It is seen that the rating of a suitable fuse is a standard one but it should cover the required delay in the tripping process. This is important point in order to prevent switching off at the starting condition due to the high values of starting current. For example some pictures for different types of HV fuses may be proposed in Fig. 4 – 19. Whatever, fuses are a good active tool on the distribution networks at level of 400 V or 220 V (Fig. 4 – 20) where they are simply used and repaired quickly. Consequentially, some types are used as:

a) Fast Acting Fuse

It is a fast acting (tripping) but after the time of starting current. This means that the tripping cannot be set on a time less than the starting time where the current is high.



b) Time delay Fuse

It is suitable for the overload protection principle where its time delay is normally about 10 s. This is a disadvantage phenomenon because it will be delayed at the actual short circuit condition. This may lead to the failure of the insulation in spite of this hurt may be accumulated to be at high effect after many times of short circuit. Thus, the aging of the motor will be highly decreased.

c) Multipurpose Fuse

It is contain both above types of fuses and it works with many items.

d) Current Limiting Fuse

It reduces the short circuit current to improve the performance of circuit current interruption.

10- Fused Link

This is another advanced type for the fuse utility as is a fuse which is installed on the arm of an isolating link. It may be more suitable for the process of changing a fuse in spite of the fuse holder that can cover the problem. This is not the reason for the use of this fused kink but it is more practical to treat.

4 – 3: VOLTAGE LIMITER DEVICE

In this case an electric circuit needs to be protected against the presence of high danger values of voltages as well as the heavy currents. For currents, a protection device can operate either for a suddenly high increase in the values of current or a case of overloading or any other. On the other hand voltage takes two different directions as that of current as well as another one. That is the outside of voltages due to natural disasters. Thus, some new elements should be introduced for covering the problem.



Fig. 4 - 21 : Surge Arresters

1- Arresters

On contrary for the circuit breaking, there is the closing on a circuit completely. This means that the electric circuit would be shorten completely although it is operating normally. The given idea may not explained well but it gives us a protection for the operating electric circuit. Also, a circuit should be protected against electric disasters where it may be subjected to a sever values.
Whatever, a protection system can operate for tripping the circuit with higher values of currents while another type of protection with electric disasters. These disasters means an emergency condition for a small period of time.
It can be simply appeared with motors as starting currents but it would be an electric impulse for a micro seconds durations. Then, such impulse can be generated due to lightning strokes that have a high energy for a short time and consequently, there will be no need for breaking the circuit as a solution. This point is treated through a device called as "ARRESTER". Some shapes of arresters are given in Fig. 4 – 21 for different voltage levels. Their shape like that of voltage transformer but here there is an added ring at the top of arrester. This insulating rod contain a nonlinear resistance inside in spite of its different types and theories of acting with the induced high values of voltages in the power system. Arresters don't break the circuit but contrary they make a short circuit on

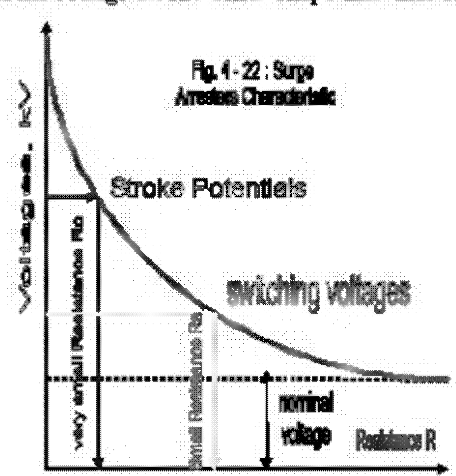


Fig. 4 - 22 : Surge Arresters Characteristic

allover the circuit. This means that an arrester will be connected instead of the main circuit through the terminal of a circuit.
It is a resistive element inside the system where it is located at the HV

point of each phase. Its resistance (Semi-Conductor) is very high so that can be considered as infinity with any operating condition. An arrester can be connected at the highest point to the phase of power system (one for each phase). It is an nonlinear impedance of negative type where its general performance is illustrated in Fig. 4 – 22.
It is seen from this characteristic that there two levels of operating conditions for the arresters in power systems. First is the lightning surges level where the voltages appears to be in MV levels and consequently the resistance of the arrester will be very small. Second condition appears when the switching processes occurred inside the network it appeared either due to faulty clearance or due to the normal operating processes of connecting or isolating different parts in the power system. Also, it should be mentioned that the resistance of arrester would be infinity for the nominal operating voltage. Generally, arresters must be installed at terminals of windings as well as at station entrances and on bus bars. Since the high voltage point is connected to upper terminal of arrester, the other terminal should be connected to earth through a counter. This counter will indicate the number of actions that taken by a certain specified arrester.

2 - Anti Surges

Another type is required to cover the phenomenon of lightning strokes inside the network where these strokes may go directly to the points of HV on the land. These points must have a high electric stress as it is a metallic point. In another way, a non potential points may be a

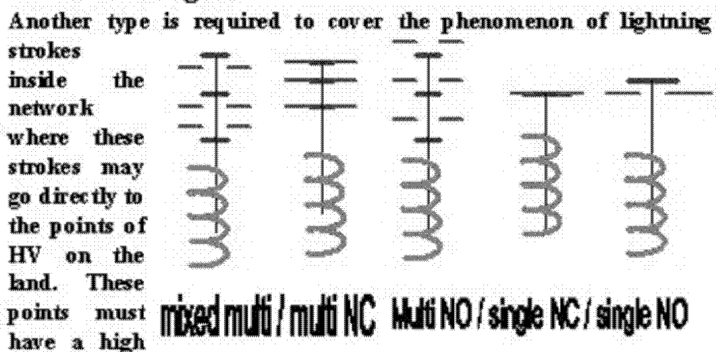


Fig. 4 - 23 : Types of Contactors

good way for the direction of strokes towards the land. This can be the earthed metallic points in the system either inside an electric station or at the tops of connectors between them. Then, arresters in another shape may be the best solution and so, anti surge rods will be the aim. They represent an actual sharp metallic edge at a top point to get the strokes before any other point. This may be classified into:

a) Rods

These rods must be very thin in diameter while its upper end is sharpened as a needle. This needle will be the very high electric point upper all other metallic points and zones. It is normally applied at the tops of a station as well as at the tops of many other components such as towers and high buildings.

b) Ground Wires

These wires are a good points as a metallic concentrated stress even it is round in shape or without an electric potential. They are usually installed as Ground wires on the towers of Transmission Lines. It should be mentioned that these wires cover a certain area under it through a protective angle of about 30 ° with vertical axis. They can be installed as:

i - Above phases of overhead transmission lines
ii- Above the switchgear of an outdoor electric station

These wires represent a good connecting way for the current comes to if a stroke hits a point on them. It is a shorted point to earth that will prevent any conduction with the elements of power systems. Also, if the strokes go directly to the land away from these wires an induced mutual voltage would be appeared on these ground wires with a relatively high values. They will pass too to the earth.

4 - 4: CONTACTORS

Contactors plays a great role in the process of connecting and disconnecting points in a circuit and so, Fig. 4 – 23 presents different styles of contactors that depending on the electromagnetic forces

induced in the coil. It consists of two types of contacts as:

i- Main contacts

They are the main contactors inside the main circuit as they will be 3 in a 3 phase system or 1 in a single phase system.

ii- Auxiliary contacts

These contacts are sub main contacts and they help the main one to realize the aimed target.
These contactors may be expressed into two main categories as follows:

I- Classifications of Contactors

On the other hand, contactors may be classified according to their contacts in the following form:

1- Single Contact contactor

It takes two positions for its contact as:

a) Normally Opened Contact

This is the most common type used in all fields while it is defined as (NO). It has a simple logic style since it will be closed if there is something wrong. This wrong case is the aimed detection of a circuit.

b) Normally Closed Contact

This is the opposite position for the above although both are doing the aimed target. It is expressed by (NC) as it will be opened if a wrong situation has been happened.

2- Multi Contact contactor

In this case different contacts may be included inside although some of them may be NO and others will be NC. This has been given in Fig. 4 – 24 where all contacts either main or auxiliary are shown together.
A general application can be a sample for its importance and then a standard values for 3- Pole 400 V contactors are

listed in Table 4 – 5. This tends to specify that all components even auxiliaries would have standard specifications, specified internationally.

Also, contactors can be tailored in the following as some important types:

Table 4 – 5 : standard specifications for 3-Pole, 400 V contactors

Motor power	current	= Temp. (A) C'55	auxiliary	Motor power	Nominal current	Temp. =55°C (A)	auxiliary
KW	3 ϕ	1 ϕ	NC / NO	KW	3 ϕ	1 ϕ	NC / NO
4	9	25	1/-, -/1	22	50	80	1/1
5.5	12	25	1/-, -/1	30	65	80	1/1
7.5	18	32	1/-, -/1	37	80	125	1/1
11	25	40	1/-, -/1	45	95	125	1/1
15	32	50	1/-, -/1	55	115	200	
18.5	38	50/60	1/-, -/1, 1/1	75	150	200	

1- Mechanical Contactor

It is a part of mechanism moving for a certain distance to give a specified force on contacting.

2- Electro mechanical Contactor

It is operating according to an induced electromagnetic field in a coil carrying current where contactors of NC type are used in this case.

3- Pneumatic Contactor

This contactor is working with air pushing (pressured air) without a direct electric effect while this mechanical pressure will act to close or open a contactor or contactors. Then a circuit will be energized.

4- Electro-Pneumatic Contactor

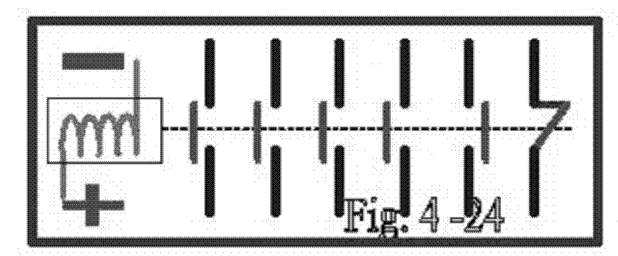
In this type of contactors, another effect to the above last type (air pressure) would be added. It may be automatic control through electricity. This suites for valves operating is large or even small systems specially in pipe line systems.

Table 4 – 6: Specification and operation conditions of contactors.

Operating time, s	Power factor	Current ratio (cut / nominal)	range	*position*
Specified conditions	0.8	1.5	AC-1	Conditions (close / open)
	0.65	4	AC-2	
	0.45 (up to 100 A)	8	AC-3	
		10	AC-4	
	0.35 (above 100 A)	8	AC-7b	
		6	AC-8a	
		6	AC-8b	
	0.45	3	AC-5a	
With transformer at AC-3			AC-6a	
Capacitive load tests with thermal effects			AC-6b	
Specified conditions	0.8	1.5	AC-7a	
60	Test with lamps	1.5	AC-5b	
10	0.05 s , close	10	AC-3	close
10		12	AC-4	

5- Latched Contactor

Here a latch may be the acting mechanical process that acting for opening or closing a contactor but it must act according to either an electric or electromagnetic fields or a pressed air. This has been explained above but its disadvantages may be concluded in the reset process. This is appeared due to the necessity for external need to rest the position of contactors. This means that the automatic reset may be absent.



6- Vacuum Contactor

A good sealed contactors will be presented where the volume inside the envelope must be evacuated. This is a system where its performance specifications are standardized. So, it is defined according a standard specification that leads to a perfect acting processes. Generally, the overall style of contactors may be drawn in Fig. 4 – 24 where all conditions can cleared. Also, the temperature is always plays a major role in the efficiency of action of contactors. These specifications and requirements of operation are collected in *Table 4 – 6.*

7 - PUSH BUTTIONS

This is a good concept due to the isolation between switching ON and switching OFF switch so that it permits the operation without mistakes. It consists of a switch OFF to open the circuit where its contactors are closed at its open position. Also, another switch ON makes the same process but for closing the circuit where its contactors become opened.

Third switch would be a mixed switch ON – OFF with two contacting points. So, one of them in a closed position while another at opening. Then, an indicating lamp would be inserted in the circuit in order to indicate the situation of the connection.

II - Methods of Operations

Methods of operations for contactors mainly can be defined in three types that are drawn in Fig. 4 – 25 for more illustration of theses methods in a control circuits. A relay may utilize such concepts to reach the target. They may be tailored as:

1 - Series Sealing

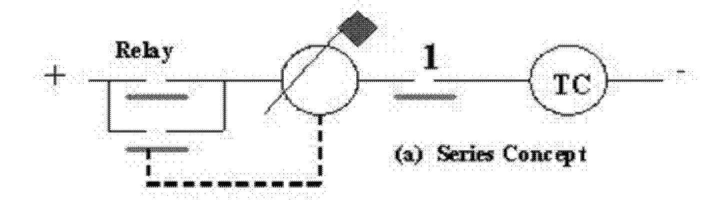
These circuits are mainly used in circuits that working with cutting order (tripping style) for secondary breakers. They are a good vital tool in both control and protection circuits. This secondary breaker may be marked as switch No. 1 in Fig. 4 – 25 where it is usually NO type. It uses the D C supply for the secondary breaker when it is working either as in our case in series or others (Fig. 4 – 25 (a)).

3 - Series Shunt

It can be defined as mixed connection type where both series and parallel are applied inside a circuit. It mixes both above connections together as the order may be directed towards a secondary switch in the tripping circuit as shown in Fig. 4 – 25 (c).
On the other side standard specifications must be considered for the choice or design such circuits to operate so that they may be indicated as:

a) Current rating

This means the ability to work with a safe value of currents which can be rated as a maximum permissible current through the contacts of contactors. A good level of currents will give a long life and vise versa.



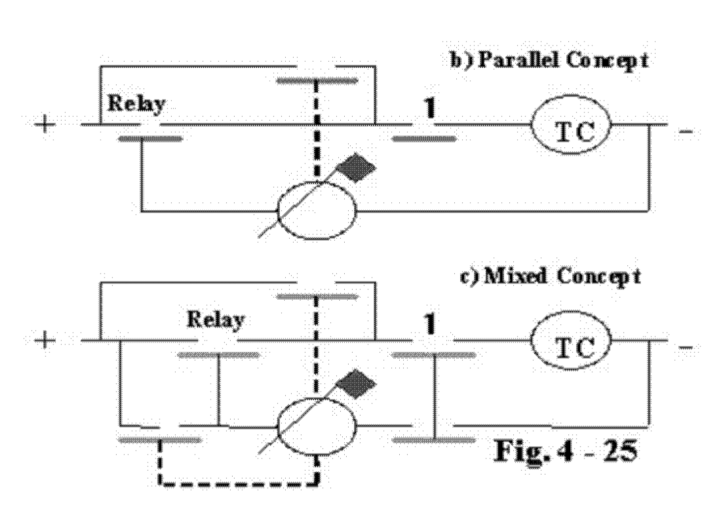


Fig. 4 - 25

b) Supply Voltage

Supply may be the main one or another in order to raise the reliability factor. It is rated at either main supply value or that for DC supply such as 12 or 24 or 48 V.

c) Number of auxiliary contacts

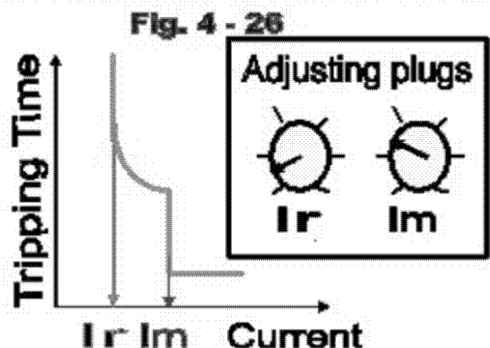
the increase in numbers of auxiliary contacts gives a chance for good maintenance but it should be studied economically too. This is illustrated before as given in Fig. 4 – 24.

4 – 5: LOW VOLTAGE SWITCHES

Electric stations are characterized with all levels installations starting with UHV ending with 110 DC voltage through different low voltages such as 400 (220) V levels. Then, all items must be indicated for the facility of a good reliable design. So, the low voltage isolators and switches may represent a vital subject to be introduced. Nowadays, there are many and more many of these switches that can not be collected to be inside a part of a book chapter since some main of them may be selected to illustrate.

1- Isolator

It is a small low voltage isolating link which is normally known as a knife. It has two connectors as that of HV links but here one of the two connectors must be fixed. The second contact will be a moving contact and consequently, the isolator must be installed on the wall vertically. For safety engineering principle, the axis of the moving contact should be at the



bottom of the knife so that for releasing conditions either by gravity or other disasters it may move down. This leads to break the circuit which means a better case than the opposite condition. In this opposite, the moving contact may released and so it will close the circuit without worrying. This is a danger case that must be eliminated completely from the possibilities (See Fig. 4 – 25).

2- Simple Breaker

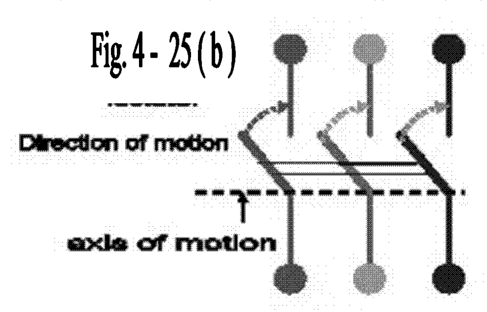
It is a simple air switch that depends on interruption of small values of currents as that less than 2 A.

3- Compact Breaker

It is a combination of both two above (simple breaker and isolator) to work together in one. It is more practicable as it is widely used in the field of workshops and industrial locations.

4- Thermal Breaker

Two currents affect the setting of tripping as they are the magnetic thermal current and that of delay tripping. Both of them can be adjusted for each branch circuit. These positions of setting are defined as a ratio to the rating value (Fig. 4 – 26) where the working characteristics are drawn in the figure. It presents an accurate discrimination to operate. The shown performance can be varied according to the setting of each value either rated current I_r or magnetic current I_m in spite of a great expanded zone for the current may be implemented.



These breakers are successively applied for the protection of either generators or long cables according to the magnetic thermal characteristics because it has tripping values of 7 – 10 times of the rated current. Contrary to magnetic effect, there is another concept for tripping which is defined as electronic switching. The characteristics of this breaker as given in Fig. 4 – 27 where an accurate setting for magnetic current I_m, rated opening current I_r and short circuit current I_o can be realized.

However, Fig. 4 – 28 presents the characteristics for a third concept for operating performance where the time setting is appeared where it is used for high rated currents. I Then, thermal effect indicates the short circuit presence while the magnetic current may be adjusted at 10 – 14 times of the rated value. Electronic tripping depends on the

time setting in the last stage of the given characteristics.
It is normally installed for electric motors as a thermal device with a setting of 10 – 13 times of the rated value Also, it can be adjusted for cables at thermal value of 10 – 14 of the rated current.

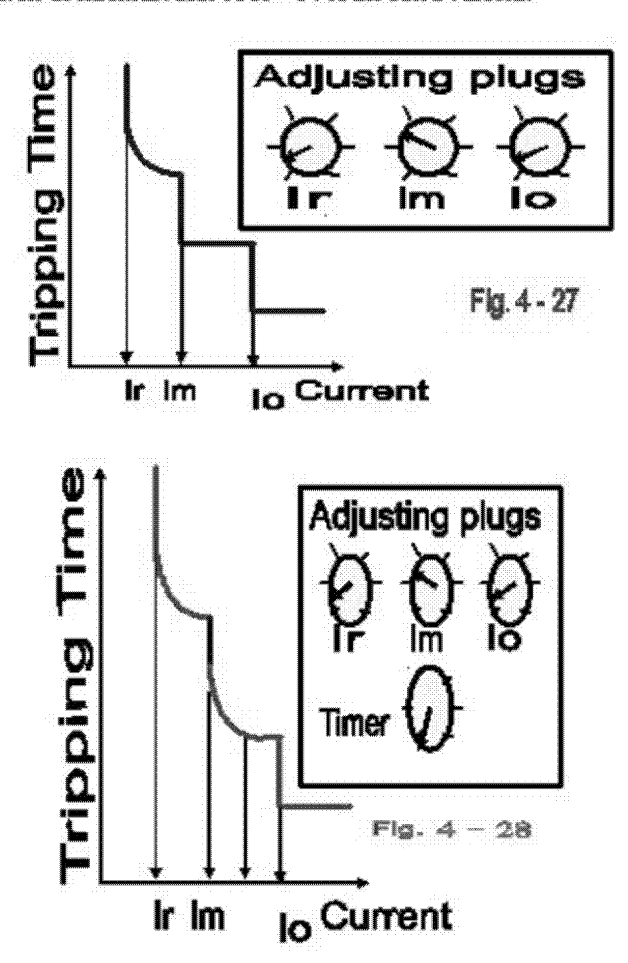


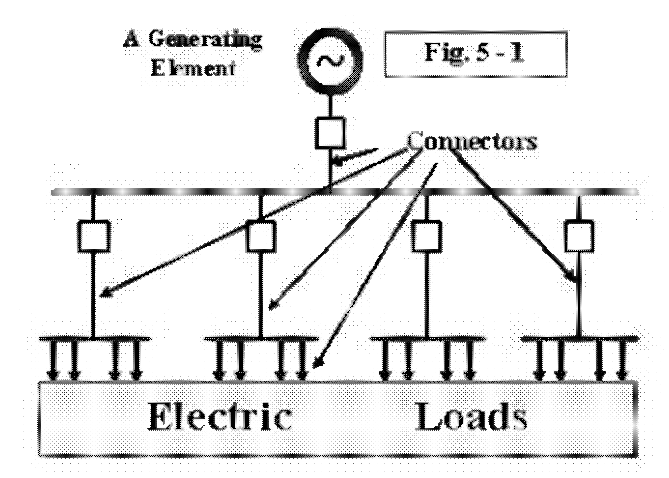
Fig. 4 - 27

Fig. 4 – 28

Chapter V

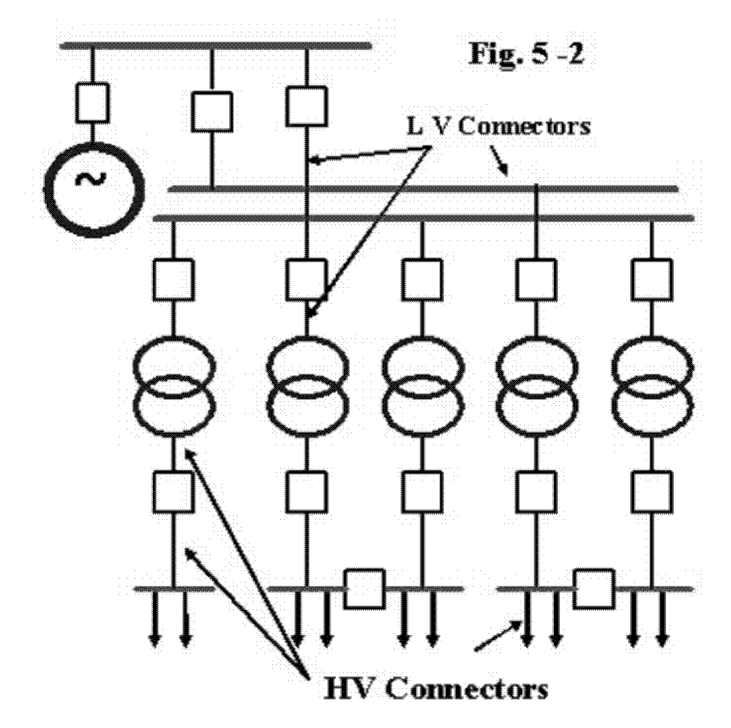
CONNECTORS

The title of electric power systems points to a great complicated style of components with different shapes. It mainly includes various characteristics even for the same components but this variety raise the difficulty level of its operation. Also, this may be reflected into other parts of this network where it must confirm a continuous supply at any time with all conditions of operations.



Electric power systems depend on a generating element and a load terminal in its simplest shape. On the other, this basic concept needs a connector in order to connect both generating and load sides as indicated in Fig. 5 - 1. Whatever, it is important to indicate that some added elements may be required in order to either modify or control the process of feeding the generated power to the loads. Thus, the transmission section of power systems is classified to be as a general part of the electric network contents. Also, this style of explanation would help in understanding the meaning of the network operation as well as its design.

Consequently, the terminal side is called as the distribution network as a component of the power networks. A power system may be designed as *uninterruptible power supply (UPS) to confirm the continuous feeding the electric power to any load connected.*
If we indicate the basic requirement for the electric power networks, it should be mentioned that each element of the terminals would need some other connectors. Then, in the present chapter we can present both requirements for either the connection between terminal sides or inside each terminal.

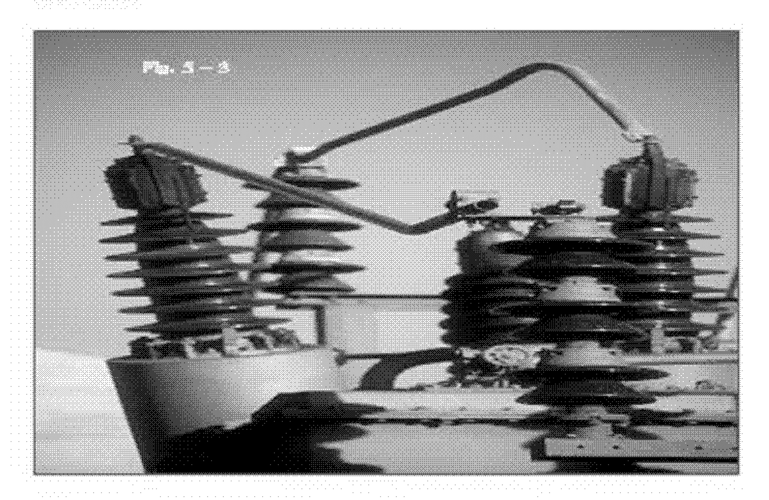


5 - 1: INTERNAL CONNECTORS

Although the connectors of Fig. 5 – 1 show the connection between the station and loads, there are another type of connections inside the station itself. This means that, the connectors required for the operation of a station. This connection may be illustrated as given in Fig. 5 – 2 where these connectors may be classified as:

1- HV connectors

This type of connectors contains the connections of bus bars at the HV side as well as all connections between elements of a cell inside. This may be more clear with the external type of connectors (Fig. 5 – 2). It takes the HV parts either that supported on land or that all suspension wires on towers or trusses. It may be wires or stranded wires or pipes or bars as shown, in Fig. 5 – 3 for example, for the connection between a transformer terminal and the connected point in the cell.


Fig. 5 – 3

2- LV connectors

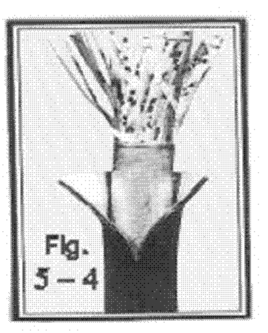
It is similar to that at HV but for the low voltage side where it is characterized with shorter distance length as well as a smaller

spacing between wires (Fig. 5 – 2). LV connections inside a station are more in quantity or in spreading since the stations consumes different powers for all voltage levels at the low voltage side. It supplies the auxiliaries ad normal loads of a station. In some special cases this side consumes more power than normal stations. Insulated wires are normally applied in most of LV distributors as the insulation must be specified as given for a sample of such wires (Table 5 – 1). The heat effect (temperature effect) has been tabulated.

Table 5 – 1: Sample for the specifications for the resistance in Ω of LV wires (PVC insulated) at different temperatures

kV	24°C	50°C	60°C	65°C
1	5 - 100			0.005 - 30
6	30 - 100			
10			30	
35		30		

3- Secondary connectors



There are many and many of connections either for telecommunication or direct connections, where both types are used inside all types of stations. For the telecommunication wires (Table 5 – 2, for example), a signal short wires can be the aim but for the power circuits it will need more care for economy. Such secondary connectors spread inside stations so that an economic solution would be preferable to minimize the consumption as well as the loss (Fig. 5 – 4). Some important factors must be considered such as reliability or effectively and safety. These connectors are given here shortly for only aiming the illustration style.

Also, communication wires must face the HF performance where its

value approaches 800 Hz as listed in Table 5 – 3. The inductance would be appeared with the presence of capacitance. Secondary connectors, then, include different types of connections that can be tailored mainly as follows:

Table 5 – 2: Characteristics of some light current wires (/km)

Diameter, mm	Resistance Ω,	Mean capacitance, (µF)		Maximum capacitance, (µF)	
		Up to 50 twins	More than 50 twins	Up to 50 twins	More than 50 twins
0.4	148	0.05	0.05	0.055	0.055
0.5	95	0.055	0.05	0.055	0.055
0.6	65.8	0.041	0.03	0.045	0.043
0.7	48	0.042	0.04	0.046	0.044

Table 5 – 3: Technical parameters of some communication wires (parameters /km)

D, mm	R, Ω/km	C, nF/km	Z, Ω/km	L, mH/km
0.5	184	31	1040	0.7
0.6	123	32	880	
0.7	92.5	32.5	730	
0.8	69.8	33	650	
0.9	54.6	33.5	570	
1	44.3	34	540	
1.2	30.8	34.5	425	0.6
1.4	22.6	35.5	360	
1.8	13.7	37	275	

a) Protection Connectors

Since a power system in operation, another system must supervise it. This supervision principle would prepare the good suitable weather for its operation as well as it must protect all elements of the power

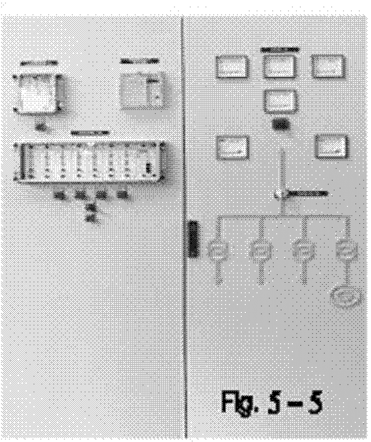
system against all abnormal conditions. This is the protective systems for the elements of either the station or even for others. Their supply must be mainly an independent so that it is normally a DC style of circuits. Hence, a special independent connections should be used and consequently this must be included in the design of stations. It would be an element of the design because the station cannot work without it.

Table 5 – 4: Basic limits for control wires with insulation.

Parameter	Sheathed wire	Control wire
Minimum resistance of insulation, MΩ/km	1000	50
AC 1 min. Testing voltage, kV	1	2
Ratio of Min. insulation strength / sheath at normal temperature, kg/mm²	1/1	1/1
Deterioration ratio %	80 / 85	85 / 85
Min. resistance of oil at 70°C, %	60 / 80	80/80
Thermal distortion at 120°C, %	50	50

b) Control Connectors

Another type of secondary connections inside a station should be installed beside that of protection. It may be called as the control circuits. Its connections would be at a low voltage level since it controls a HV equipment. The supply here may be AC or DC style according to the equipment or the circumstances. This may be important for voltage control or for alternator speed synchronism or for the synchronism control during


Fig. 5 – 5

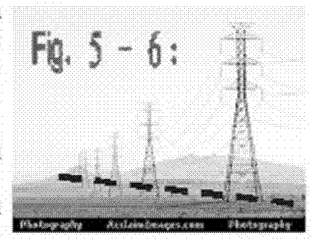
switching on operations. Then, Table 5 – 4 lists the basic limits for control wires at low currents (less than 1 A) with insulation.

c) Measurement Connectors

The used connectors (wires) in stations for the purpose of measuring some electric quantities are one of the vital secondary connections inside. It is normally needed to measure important quantities as well as some important factors for either revision or to be used for automatic control. It is usually needed also for protective circuits. This measurement may be required for the voltage at the end of transmission lines or cables or on the bus bars or at terminals of transformers. Also, the power factor measuring is an important factor and the load curve may be a good tool for revision. Fig. 5 – 5 shows a sample for the measuring values on a switch board that confirm the importance of measuring wiring.

5 - 2 : EXTERNAL CONNECTORS

Connectors either inside or outside a station means the conductor that connecting different terminals together and then, the inside station connectors are defined as internal connectors. However, the connectors outside stations take the name "External connectors" so that we may put it in details in this section. Thus, these external connectors may be classified mainly as overhead wires and underground wires (underground cables). Fig. 5 – 6 shows that all transmission lines must be located as a straight line (shorter distance) as it will be proofed by the next mathematical analysis.


Fig. 5 – 6 :

I- overhead wires

This type of wires is basically used in the transmission lines which connects two stations together. It may connect a load to a station and so on. Whatever, the transmission line must be constructed according to the engineering economic principle. So, a metal conductor can be the solution even without insulation.

Since the transmission lines go for a long distances, the non-insulated conductors will be the cheaper. Consequently, the support or handling tool to hang such conductors must be made of an insulated material. Then, a mechanical support will be needed to stand for the wires. The mathematical analysis for such cases may be given shortly below.

If the weight of a conductor per unit length is W and tension on a wire section or segment s is T.

For balance can be realized when the tension T is resolved in the Cartesian Coordinates (Fig. 5 –7) as the two components T_x and T_y (where $H = T_x$ & $T_y = Ws$), and then the angle β can be defined as:

$$\tan \beta = dy/dx = T_y / T_x = Ws / H \quad (5-1)$$

So,

$$ds = ?\ (dx^2 + dy^2)\ ,$$

$$ds/dx = ?\ (1 + (dy/dx)^2) = ?\ (1 + (Ws/H)^2) \quad (5-2)$$

or

$$dx = ds / ?\ (1 + (Ws/H)^2) \quad (5-3)$$

Integrating both sides, we get

$$X + K = (H/W)\ SINH^{-1}\ (Ws/H)$$

At origin x = s = 0 , then K = 0

$$s = (H/W)\ SINH\ (Wx/H) \quad (5-4)$$

$$dy/dx = SINH\ (Wx/H) \quad (5-5)$$

Thus, by integration ew deduce that

$$y = ?SINH\ (Wx/H)\ dx = (H / W)\ COSH\ (Wx / H) + K \quad (5-6)$$

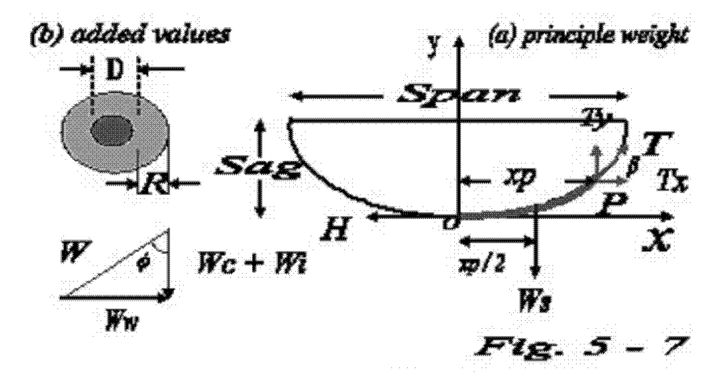
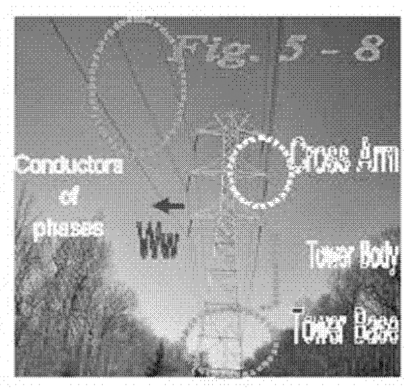


Fig. 5 – 7



At x = y = 0 , K = -(H / W)

So,

$$y = (H / W) [COSH (Wx / H) - 1] \quad (5-7)$$

This is the catenary's equation and then the overall distance on the x axis is called "span". Also, the max value for the difference between highest and lowest points of the conductor will be known as "Sag" as indicated on the figure (Fig. 5 – 7). Thus, the final tension T would be found as:

$$T^2 = T_y^2 + T_x^2 = H^2 + W^2 S^2$$
$$= H^2 + H^2 \ SINH^2 (Wx/H)$$
$$= H^2 \ COSH^2 (Wx / H) \quad (5-8)$$

Finally,

$$T = H \ \text{COSH}\ (Wx / H) \qquad (5-9)$$

However, the design of a line must face all conditions of weathers and even disasters so that a complete resultant forces may be deduced with the presence of ice and wind. This leads to a new added weight and force to that calculated above as shown in Fig. 5 – 7 (b).

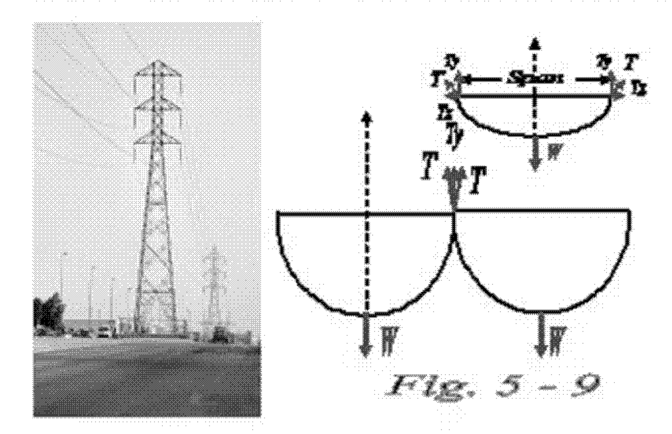


Fig. 5 – 9

Hence, the total conductor weight will the original conductor weight (W_c) plus the added layer of ice (W_i) while the wind pressure (W_w) may be perpendicular to vertical (acts horizontally). The effect of wind appears very well with the suspension towers because it is designed for the vertical loading as shown in Fig. 5 – 8. The final mathematical result of weights will be:

$$W^2 = (W_c + W_i)^2 + W_w^2 \qquad (5-10)$$
$$\text{at} \quad \tan \phi = W_w / (W_c + W_i)$$

When the level of the wire ends is the same the tension will be too the same and so, the resultant T_x will be zero, then only the vertical gravity weight W will act.

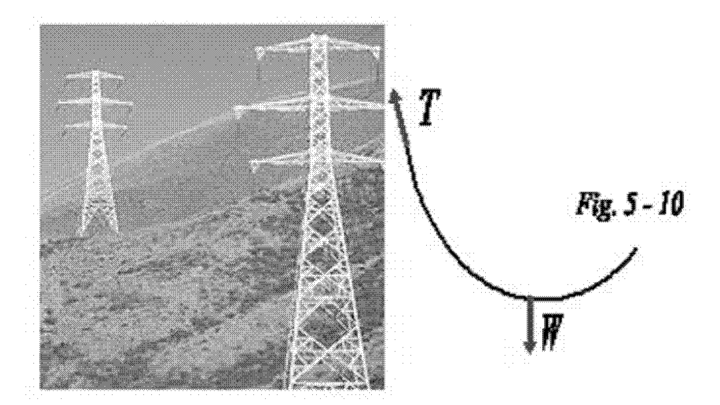


Fig. 5 - 10

This gives a physical engineering meaning that we can simply suspend the wires in this case (Fig. 5 – 9). So, we can use multi suspension connections as suspension as shown in Fig. 5 – 9 in order to minimize the cost of supporting tools (towers). Contrary, this needs a tie point in a place to cover the actual conditions. In this case the tie problem will appear. Also, if both ends of a wire are located in different levels (Fig. 5 – 10), terminal final tension will be also different. It is the geographic property of a land. Then, the suspension style will be impossible. Accordingly, a transmission line may be constructed with a large number of towers to suspend the wire with another type to make the required tie point. Thus, a line consists of

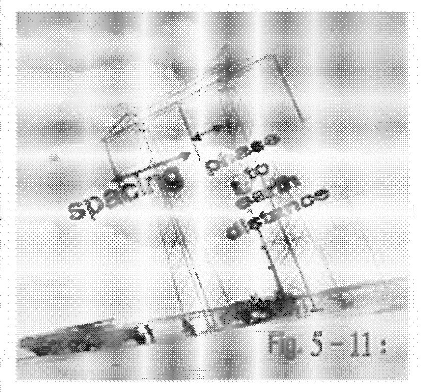


Fig. 5 – 11 :

towers used should be explained. Towers of a transmission line may be classified as:

1- Normal Suspension tower

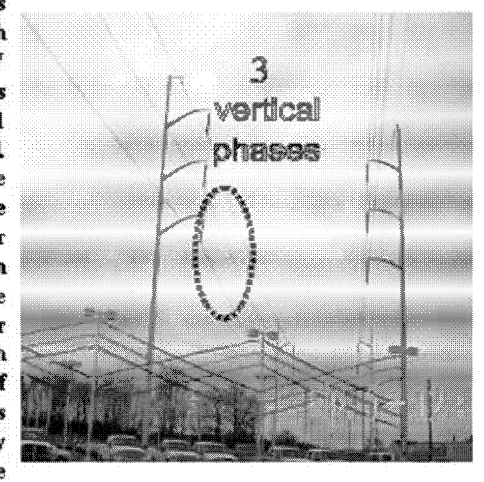
It is the lowest price for towers as a whole as it represents the most usable type of towers. It depends on many factors which affect the value and need for towers. Then, a type classification may be inserted here in order to minimize the cost of a station design. This may be explained as given below.

I- Single Circuit Suspension tower

This is shown for example in Fig. 5 – 11 where the conductors of phases lie on a horizontal line. On the other hand, the classification of towers in this section may be based on the geometry of phases and consequently it can be classified as:

1- Horizontal phases towers

This type of towers in very needed with EHV and UHV transmission lines as given in Fig. 5 – 11 for the 500 kV level. This means that the lower voltage permits a shorter spacing between phases so that the cross arm of a tower can be smaller. With higher levels of voltage the cross arm will practically cost more and more not only for the cross arm only but also for the body of the tower itself.



2- Vertical phases towers

On the other side, a vertical spacing for the phases of a circuit may be most economic especially with low voltage levels. This is given in Fig. 5 – 12 where individual tower for each circuit has been applied.

3- Triangle phases tower

This another allocation for phases is normally suitable for the medium levels of HV when the spacing can be arranged in the triangle shape. It should be mentioned that the triangle has always an equal spacing but the projection of the upper conductor must not lies exactly above that of the lower one.

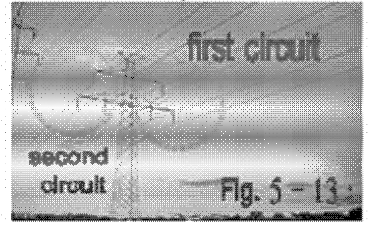


Fig. 5 – 13

This is indicated well in Fig. 5 – 13. This tower hangs two circuits but each circuit is located in a triangle shape.

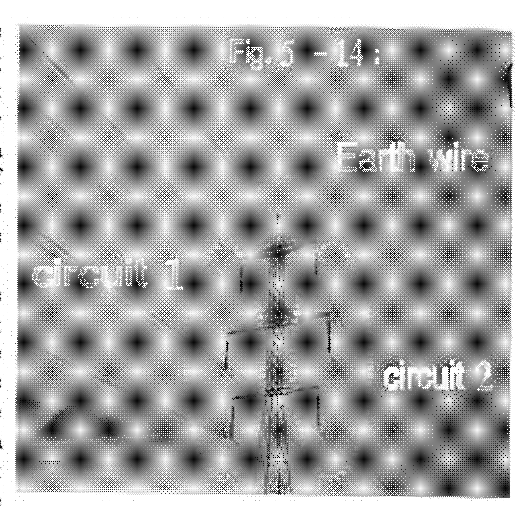
II- Double Circuit Suspension tower

Since the transmitted power is increased, a partition for the transmitted power may be the best solution. This will minimize the conductor diameter as well the increase in the reliability level in operation. Then a single tower can be used for supporting two circuits as shown in Fig. 5 – 13 where each circuit takes a side. This is an economic solution for the spreading of transmission lines between stations and consequently between stations and loads.

Although the classification for the towers according to the circuits supported (single or double circuit style) is a good tool, each of both can be tailored according to the insulating string shape or style. Whatever, each type of classification would inserted inside too. This may be written in the form:

A) Single String (Single / Double) Circuit Suspension Tower

Fig. 5 – 14 presents a Single String Double Circuit Suspension tower where the earth wire at the top of this tower is pointed. It is always at the top point of towers along its length. It covers the lightning strokes protection for the phases of both circuits. This point also should be locally earthed through a tower footing resistance in order to minimize the resistance to earth through it.



b) Double String (Single / Double) Circuit Suspension tower

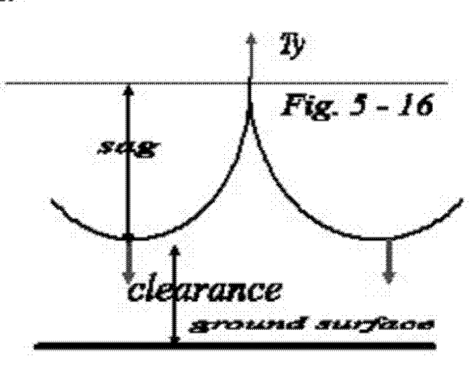
It looks like the first one but a double string of insulators is used instead of one shown in Fig. 5 – 14. The specified double string towers for double circuits is also varied in shape and consequently its shape may be deduced as:

i- V Shape String (Single / Double) Circuit Suspension tower

It is recommended in the area where the wind activity is high and so, it can be used for single or double circuit types. This is illustrated in Fig. 5 – 15 for a HV level the tension and its span would be large.

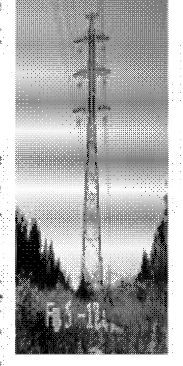
ii- II Shape String (Single / Double) Circuit Suspension tower

Here the string is parallel to the other one and the tension must be divided exactly between both strings in order to raise the mechanical resistance of the string against loads. This would be presented later with other types of towers in the present section.



iii- A Shape (opposite V shape) String (Single / Double) Circuit Suspension tower

It is a type of mechanical bolting to raise the quality of resistance against vibrations or twisting of conductors.



2- High Suspension tower

Sometimes if we need to pass on a revere or inside a wide sea, the normal suspension tower cannot be applied. Then, another concept may be necessary although a high level for the conductors of phases must be a base in this case. Although we need such high levels of conductor, we use the suspension of high type due to its low price relative to all other types of towers. The main principle for the balance of mechanical forces is given in Fig. 5 – 16. This shows a single high tower use which is connected to two other similar towers while for a larger distance many of high suspension towers would be required.

The mechanical distribution of loads in this case will be the same as for the normal suspension towers as:

a) Single String (Single / Double) Circuit Suspension tower

b) Double String (Single / Double) Circuit Suspension tower

An image for a high tower is given in Fig. 5 - 17 that indicates that it is the same as the normal suspension tower but with a great height.

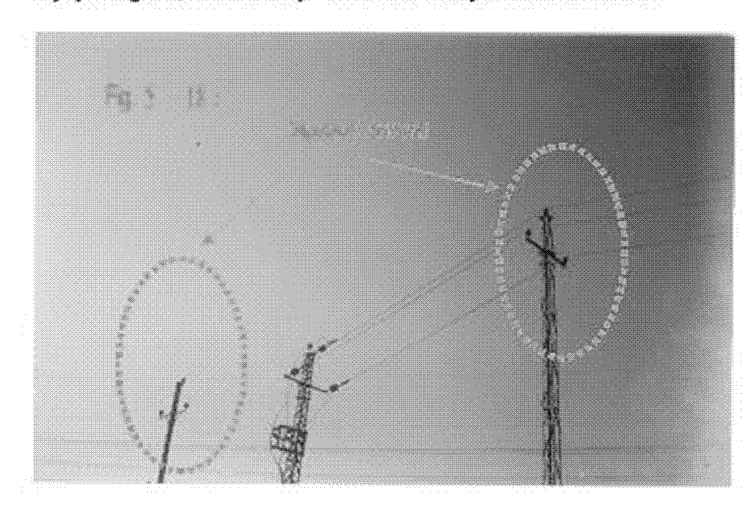
3- Support tower

The support tower is the same as the suspension tower except that the insulating string in the suspension becomes a supporting rod installed on the cross arm instead of hanging. This is shown, for example, in Fig. 5 – 18 where the level of voltage is lower as well as it is spread in the single circuit conditions.

Similarly, it may be classified approximately as the suspension type as:

a) (Single / Double) Circuit support tower

b) (Single / Double) Circuit Suspension tower



In the given condition of supporting there is a small swing angle for the supported conductors on the insulating support. It can be single or double circuit towers while the string is always as a single. This may vary and deviated for the transmission lines feeding the electric train networks.

4- Tension tower

Tension tower which may be defined as "Anchor Tower" is a more complicated tower than that of suspension. This would be appeared due to the maximum mechanical tension presented at the terminals of a wire. Then, a different shape may be shown as the insulating string will be approximately a horizontal string. It was exactly vertical string in the suspension towers. Also, a comparison is given in Table 5 – 5.



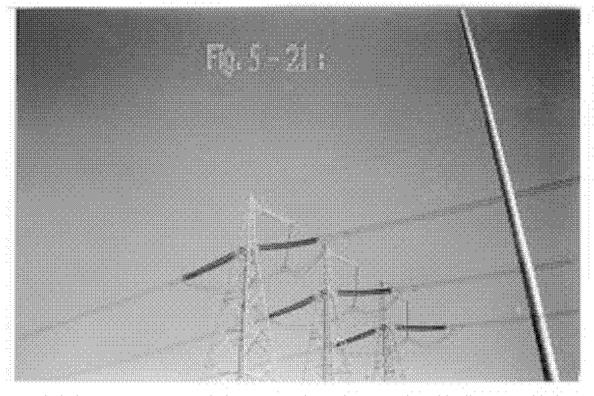
a) Single String (Single / Double) Circuit Tension tower

Fig. 5 – 19 gives a Single String Single Circuit tension tower where the base of this tower is a wide relative to the above suspension towers. It can be mentioned that the level of voltage is about the medium levels of HV in networks.

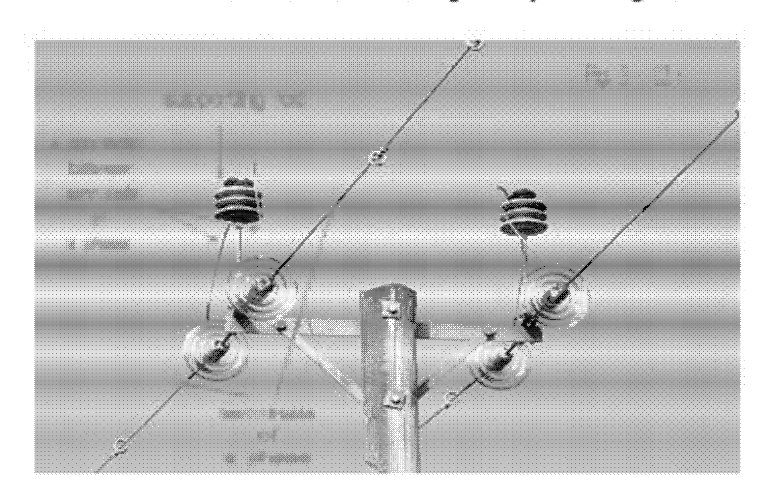
Table 5 - 5: Comparison between Towers

Type of Tower	suspension	tension
Height	high	short
Insulating string	vertical	horizontal
Tension	low	high
base	thin	wide
price	cheap	expensive
Quantity content	large	small

b) Double String (Single / Double) Circuit Tension tower

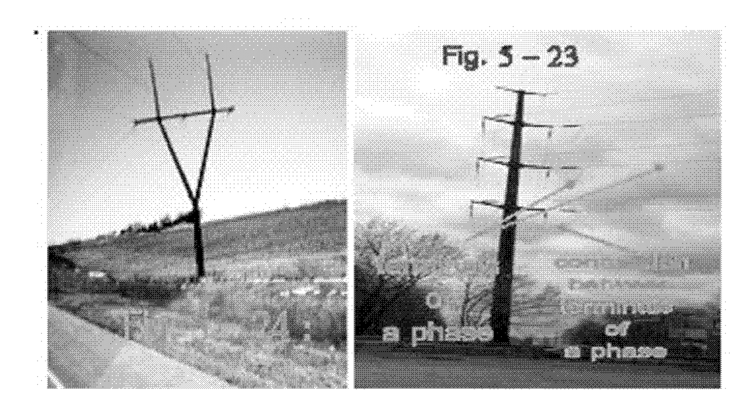


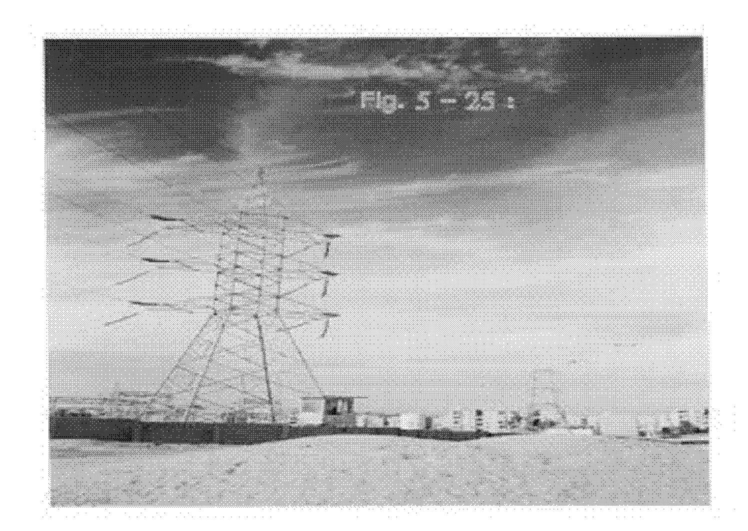
It is important to say that this type of tension towers is more spread due to the great growth of generated power and transmitted or utilized in all electric power systems in general.

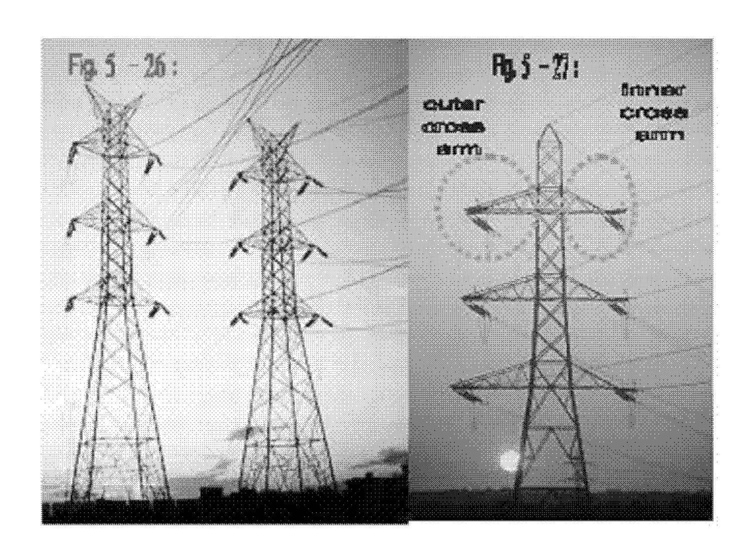


This type of towers is shown in Fig. 5 – 20 for a Double String Double Circuit Tension tower. Contrary for higher voltages a Double String Single Circuit Tension tower is shown in Fig. 5 – 21 where the operating voltage of this line 500 kV. A great difference in

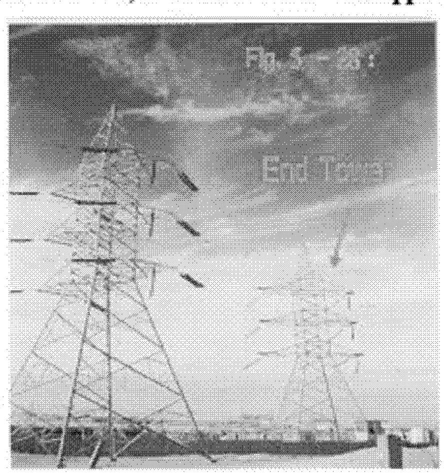
construction and shape of both last tension towers shown in Fig. 5-20 and Fig. 5 – 21. Also, Fig. 5 -22 presents a single string rod single circuit tension tower where only two phases are seen in the figure.







It is remarked from Fig. 5 – 22 that, the tension tower for support type towers of transmission lines differs only in that the supporting string is used for the connection between both terminals of a conductor of a phase in the suspension type while a support rod is used for this connection for the support type of towers.

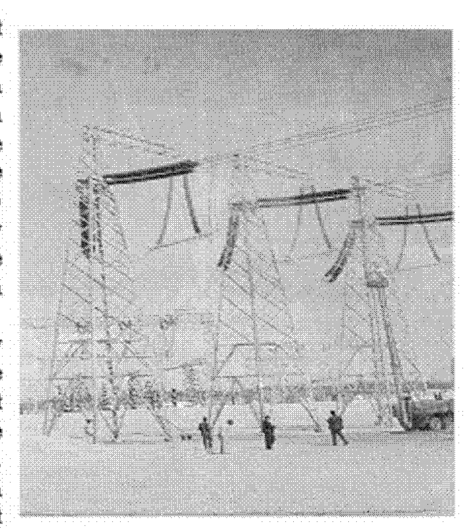


It is seen that the tension tower is required for the transmission line in order to tie the terminals of a conductor roll.

This means that it is a major type in the process of installation of towers of a transmission line.
It is important to mention that a tension tower is needed at any crossing for either streets or rivers or roads or even at any area of populations. This will minimize the risk factor for faults. Thus with such crossing, a bottom earth grid may be used as a safety procedure. It should be included with the maximum sag or minimum clearance. This optimal condition can occurred with the maximum length of conductor over a span which must be happened at the highest weather temperature in the hot places. Contrary, this case may be occurred at winter with maximum weight if a frozen weather is appeared such as the pole area.

5- Angle tower

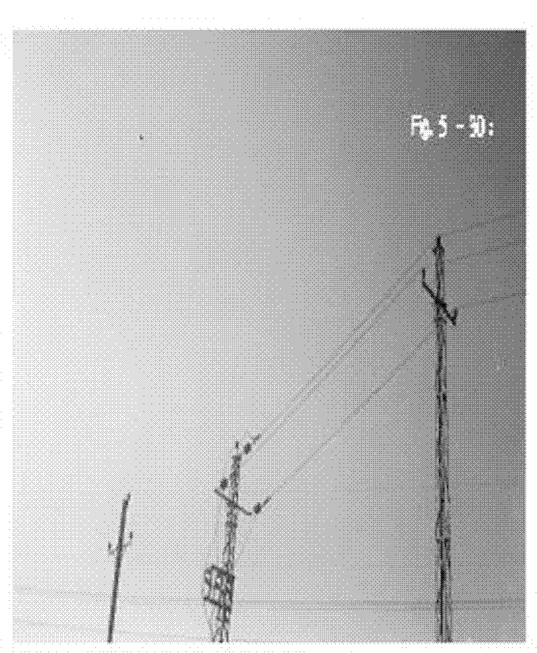
As it is said above that the transmission line must be installed in a straight line shape in order to find the minimum cost for the connector between two specified places (usually stations). Since we live on a land with geographic characteristics, we may subjected to some problems that prevent the installation of a line in a straight line. Although this condition may stop the straight



line presence, we must not apply a curve line. So, a multi straight line systems should be implemented so that an angle tower can be used. If a single angle tower will not be enough, more of angle towers should be introduced. The angle tower is more expensive than the tension tower where it is also classified as the tension towers as:

a) Single String (Single / Double) Circuit Angle tower

Fig. 5 – 23 shows a Single String Double Circuit Angle tower for a LV networks. It is remarkable that intercross arms are less in length than the outer. Also, a connecting conductor is used to connect both terminals of a phase conductors. Similarly, a single string single circuit angle tower for LV networks is given in Fig. 5 – 24.


Fig. 5 - 30:

A Single String Double Circuit Angle tower is illustrated in Fig. 5 – 25 where the difference between the lengths of inner and outer cross arms is well seen.

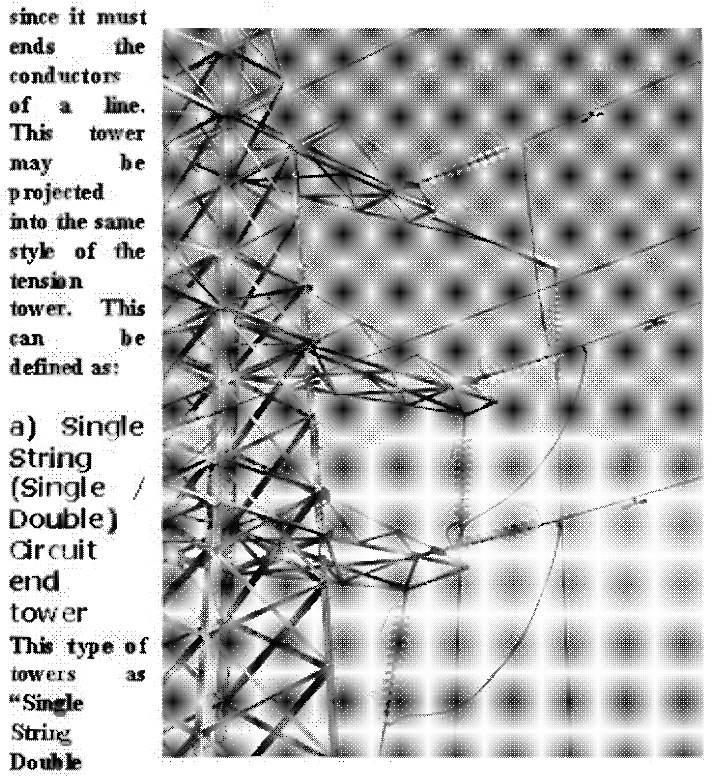
b) Double String (Single / Double) Circuit Angle tower

A Double String Double Circuit Angle tower is given in Fig. 5 – 26 with two earth wires at the top of the tower although another double string double circuit angle tower with only single earth wire is shown in Fig. 5 – 27. Both of them illustrate the necessity of such towers inside the line (or lines) of a transmission line.

Finally, tension towers are considered as a standard angle towers that means certain angles as 30˚, 45˚, 60˚ and 90˚. An important mention would be said about these angles that other angle could be created from these fundamental standard angle towers.

6- End Tower

This is a major tower in the line as it is installed at both ends of a transmission line. It also, takes the same forms of a tension tower since it must ends the conductors of a line. This tower may be projected into the same style of the tension tower. This can be defined as:



a) Single String (Single / Double) Circuit end tower

This type of towers as "Single String Double Circuit end tower" is shown in Fig. 5 – 28 where it takes two roles in the same time as an end tower as well as an angle tower.

b) Double String (Single / Double) Circuit end tower

Whatever, the mechanical strength is high a Double String would be necessary where a Double String Double Circuit end tower is used as it is shown in Fig. 5 – 29 for the EHV level of voltages. It is a single tower / phase because it is nominal for the voltage of 500 kV..
Otherwise, an end tower is generally important for two major reasons as:

1- A step down from a super high level

2- A modification for the entry of conductors towards the station.

However, a support type for end towers has been given in Fig 5 – 30 while it feeds a local distribution transformer. It supplies a transformer instead of a station at a low voltage in order to distribute its power over the local area.

7- Transposition Tower

When the length of a transmission line is increased, its fundamental parameters such as capacitance C , and inductance L for each phase will not be similar. This would be appeared due to the geometrical location of conductors of phases so that an engineering solution must be applied. Then, a similar distribution for the conductors of each phase must be found so that a replacement concept may be required. This relocating process can not be implemented directly without a special towers which in known as the transposition towers as shown in Fig. 5 – 31. These towers may be similar for the tension tower types in the form:

a) Single String (Single / Double) Circuit Transposition tower

Here, Fig. 5 – 31 presents a Single String Double Circuit Transposition tower as referred above. The transposition process is clear since the upper conductor would take the place of the middle one. Also, this middle will go to place of the lower while this lower must go to the place of the upper phase. Thus, three transposition towers (as one group) should be implemented for each long line although two groups would be needed for a longer line.

b) Double String (Single / Double) Circuit Transposition tower

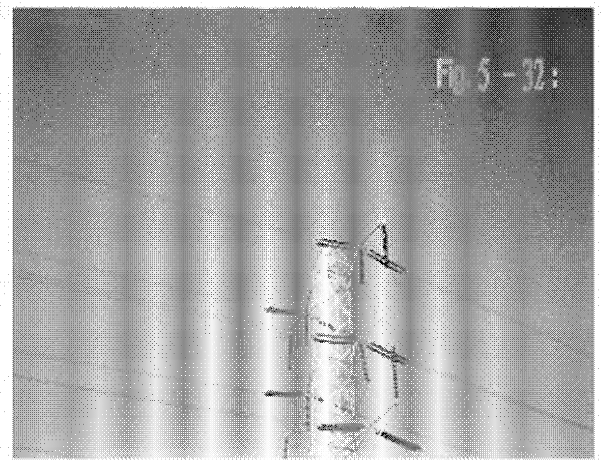
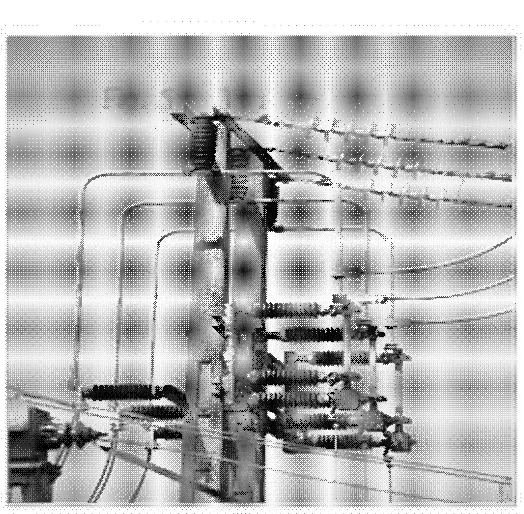


Fig. 5 - 32 :

Now, a Double String Double Circuit tower is given in Fig. 5 – 32 where stress is high due to either wind or others. It is seen that, a lot of strings are used as high load is acting. This leads to a fact that the base of transposition tower must be larger than that of tension or even angle towers. These strings are required to hang conductor during the process of



transporting a phase conductor the new place.

8 – Portal

Portal is a final horizontal phases for a transmission line but it is installed inside a station (not out). This means that the level of conductors would be directly suitable for the conductor distribution inside a station. A simple sample for end towers is shown in Fig. 5 – 33 in order to simplify the idea. Otherwise, Portal is related in a direct connection to the end tower. This means that an end tower is needed to reduce the conductor level

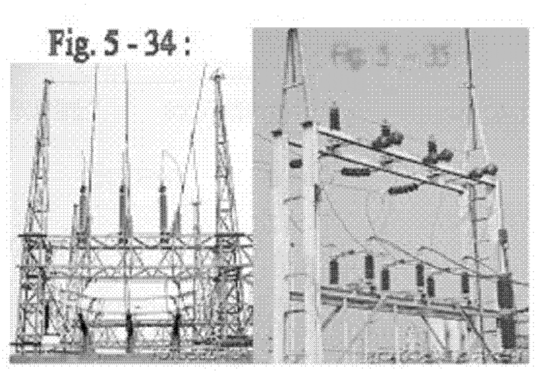
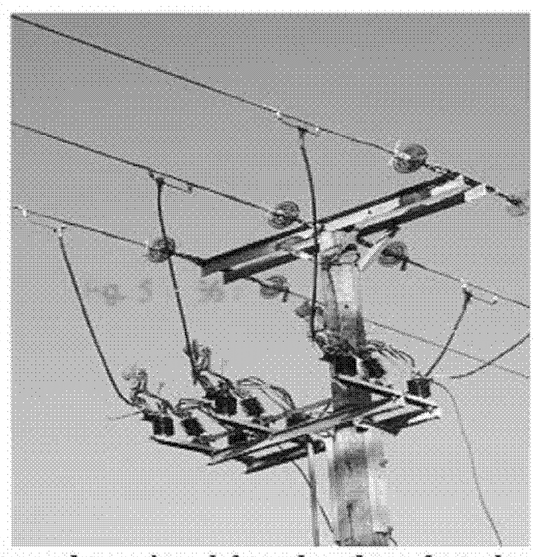


Fig. 5 - 34 :



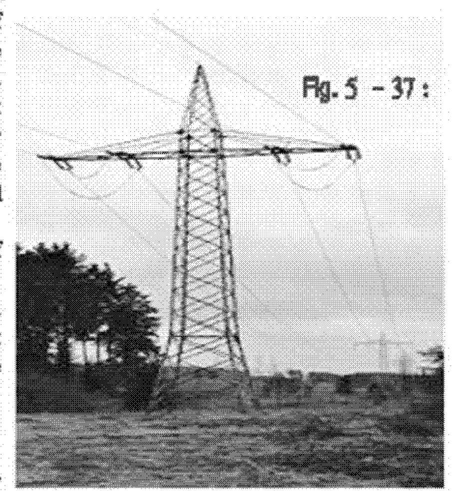
from very high height to a high level only.

Then, a portal reduces it again to the practical level for the distribution of conductors inside a station. It is remarked that the internal distribution of conductors inside this station is found as piped (not wire).

Contrary a wire connections is shown from Fig. 5 – 34 or Fig/ 5 – 35 where a portal is given at the beginning of a station.

9 – Special Towers

In spite of all above fundamental types of towers, there are many special towers for various purposes. This can be simply shown for the special tower of Fig. 5 – 36. It is a mixing between a tension tower and an end tower which may be suitable to be as a tapped tower. It looks like a tapped transformer so that it may be called as "Tapped Tower" or "Joint Tower".


Fig. 5 – 37 :

Also, another shape of special towers may be shown for example in Fig. 5 - 37 where it presents a 4 conductor type of towers. It may be used for a special application.

Hence, a special shape of towers may be applied for a specified purpose in a certain place while it must based on the rule that: the tower consists of steel or galvanized iron beams. This gives the facility to change or modify the shape or dimensions of the tower.

10 - Accessories

There are many more details but only the major accessories would

indicated in order to illustrate the importance of these small parts of a line. The most of them may be tailored as:

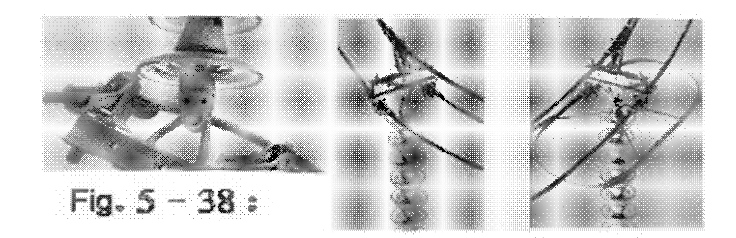


Fig. 5 – 38 :

a) Bolts

Since the construction of the iron tower is depending on some beams, a good tie will be very necessary. This can be done with bolting system.

b) Holders

These holders are varying in a wide rang because we need to hold the insulating disk as well as the conductors or other accessories. Fig 5 – 38 illustrates such type

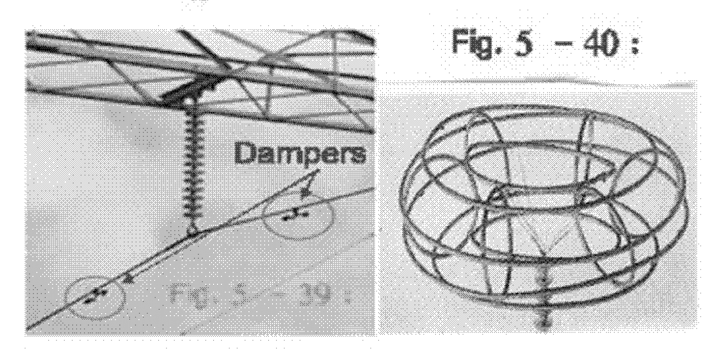


Fig. 5 – 39 :

Fig. 5 – 40 :

c) Dampers

They are a basic tool to help the balance of conductors during mechanical swing for conductors in the air. They are a weight which

gives a vertical added weight to prevent the swing process. This tool is always put at both sides of conductor on a suspension tower as given in Fig. 5 – 39.

d) Arc Ring

This ring transform the electric field along the insulating string into a homogenous field. This will raise the electric flash over voltage along it. One of its type is shown in Fig. 5 – 40.

Finally, all above mentioned items are needed for a designer of electric stations so that the general view and use would be a positive tool in a design.

II- Underground Cables

Cables are easy in use as they are put generally either in a tray or buried inside the ground. They have many types such as HV oil and gas Cables or LV Reinforced Cables as Compressed gas with polyethylene sheath or rubber cables. Some types of cables are shown in Fig. 5 – 41 where single or triple core cables are given.

Cables in general are characterized relative to the above overhead lines – in spite of its high price and stray currents to earth - in some points as:



a) Low Risk Factor

b) High Reliability

c) No Effect for Surges and Natural Disasters

d) No Faults with Birds

Its basic characteristics may be the insulation performance where a relationship between surface factor and core shape is drawn in Fig. 5 – 42. Also, relative strength between oil and gas cables is drawn in Fig. 5 – 43. while drawings of Fig. 5 – 44 for the dependency of insulation on the time of application.
There are three factors affecting the quality of cable insulations as:
a) Electric Breakdown
b) Thermal Failure
c) Internal Ionization

Table 5 – 6: Design factors

Factor	Details	Value
k_1	Represents maximum operating voltage	1.15
k_2	Probable reduction for insulation	1.25 – 1.5
k_3	Transients effect	2.25 – 2.5
k_4	Pressure Reduction of oil / gas	1.1 – 1.2

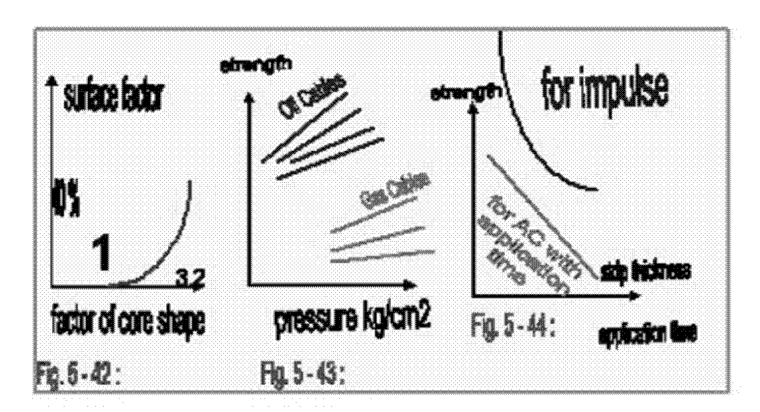
It is known that laminated insulation of cables with creep charges inside impregnated paper tapes will fast to find the weak points. The value of voltage for a cable may be designed according to the formula:

$$V_1 = k_1 \; k_2 \, k_3 \, k_4 \; [V_{rated} \;\; / ?3] \quad (5\text{-}11)$$

Table 5 – 7: Standard soil factors

moisture	Sand %	Mud %	Relative thermal, ˚C cm / W	Thermal capacity, J/g ˚C	Density, g/cm^2
high	9	14	80	2	2 – 2.8
mean	7 - 9	12 – 14	120	0.33	1.9
low	4 - 7	12 - 8	180	0.83	1.8
dry	4		240	0.8	1.43
concrete			90	0.33	2.2
Asphalt			160	1.66	1

All factors in this equation are collected in Table 5 – 6.



Thermal breakdown may be appeared due to:

a) increase of the external thermal resistance above the designed value.

b) Rise of the medium temperature

c) Electric overloading

MEASUREMENTS

Generally, connected systems in all field of life require a system of information technology. This system of information takes a general form if the connected system has a wide application. It will be a specified special information systems for local connection however, it may catch both styles of information. Thus, information technology plays a great roll in any network either it for gas or water or even for electricity.

However, electric power networks as a united network have a lot of information that needed for transmission between station together as well as between stations and dispatching centers. It is a convenient model for such systems of information so that a united system of information must be installed to supervise an electric network. This proposed information system must depend on initial fundamental data that would be a multi parameter data. So, different parameters should be measured in various unites that may be not the same. Basic unites as well as electric unites should be introduced and consequently other parameters would be deduced. Then a measurement concept would be necessary in order to fulfill all requirements of data in such systems. Thus, a formulation for the basic majority construction of such a system would be required and so, the problem of measurement may be the goal.

However, electric power systems depend on different values even non electric although the network in only directed to generate electricity energy. Whatever, power systems operate at different voltages so that recording their values may represent a problem. Thus, the present chapter illustrates the basic logic system for the building of information data for the network as a whole.

6 – 1: MEASURING CONCEPT

Measurement and detection have the same style of meaning although their titles appear to be not the same. In the present chapter these two items would be concentrated and explained in order to cover their importance in the process of design of electric stations.

This meaning of both of them may cover too the operation characteristics of a network. The target of this book a wide scope for the base of the design procedure for electric stations and then the network as a whole. This process would consume a lot of knowledge in order to reply the required level for design.

I– Measuring Units

It is known that there are many measuring systems but here we are interested in the engineering unit systems such as SI units system. Then, Fundamental units (Single units) as a basic units in the system of measurements are listed in Table 6 – 1. They are physical unites that generate all other units even engineering ones. Similarly, deduced later unites must depend completely on these basic unites but the chosen system of measurements is suitable for the engineering practical measurement.

Table 6 – 1: physical Fundamental units (Single units)

Title	Unit	Title	Unit
Time	h	length	m
Horse Power	HP	mass	kg
British Thermal Unit	BTU	Weight	kg
Thermal Unit	Cal	Current	A
Thermal Unit	Erg	Angle	rad

On the other side, other fundamental unites that relating to engineering field are tabulated in Table 6 – 2. These unites consist of double fundamental units such as for example m . m which means m^2. It is a measure for the area where its fundamental is the units of length.

Therefore, after the above analysis for the meaning of units and unit systems we may transfer towards a more practicable engineering

units as they are listed in Table 6 – 3.

Table 6 –2: Engineering Fundamental units (double units)

Title	Unit	Title	Unit
Area	m^2	Velocity	m/s
Volume	m^3	Acceleration	m/s^2
Angular velocity			rad/s

Table 6 –3: Electric units

Title	Unit	Title	Unit
frequency	Hz	Magnetic field intensity	A/m
force	N= kg m/s^2	inductance	H
Energy	J	electric field intensity	V/m
Power	W = J/s	electric field density	C/m^2
Charge	C	Magnetic field density	Tesla= Wb/m^2
voltage	V	torque	N. m
Electric flux	A. s	reactance	Ω
capacitance	F	impedance	Ω
Resistance	Ω	Active power	W
conductance	S=A/V	Reactive power	VAR
Magnetic flux	Wb=V s	Apparent power	VA

Table 6 – 4: Equivalent units

Value	Equivalent	Value	Equivalent
252 Cal	1 BTU	1 W	1 J/s
3.6 M J	1 kWh	1 HP	746 W
41.8 M Erg			1 Cal

It should be mentioned that a transfer concept is available as given below in Table 6 – 4 where some of important unites are tabulated to their equivalent values.

After that, it is indicate the prefix symbols as a list (Table 6 – 5) in order to facilitate the problem of search. This table brings are used symbols in all fields of theoretical or practical applications.

Thus, the presented unites in this section are mainly used for all engineering fields although we are proposed them for the electric power systems and their works. They cover all requirements either for operation or design a system or a part of the network.

Table 6 – 5: Standard prefix for measuring units

prefix	Symbol	value	prefix	Symbol	value
Exa	E	10^{18}	Deci	d	10^{-1}
Peta	P	10^{15}	Centi	c	10^{-2}
Tera	T	10^{12}	Milli	m	10^{-3}
Giga	G	10^{9}	Micro	μ	10^{-6}
Mega	M	10^{6}	Nano	n	10^{-9}
Kilo	k	10^{3}	Pico	p	10^{-12}
Hector	h	10^{2}	Femto	f	10^{-15}
Deka	da	10^{1}	Atto	a	10^{-18}

II - Measured Parameters

However, the units are specified as well as they can be equalized according to the transfer rules between different equivalent size of units. The formulation for the type of quantity entry may be analyzed and consequently, these values as a parameter in action would be introduced as given below.

1 - Current

Current (I) is the first parameter needed for power feeding or generation in addition to that its values in electric power systems reaches a very high level. This leads to the necessary for indirect method or secondly by sampling procedure. Currents in power systems vary in a wide extend. It has a low value at the consumer end

while takes a larger value in summation points of consumers. It reaches a very high value in HV and both EHV and UHV levels in stations. Current has a great meaning in electric circuit in general while it has a major roll in power networks. The used unit is Ampere (A) as given in Table 6 – 1 above.

2- Voltage

On the second side, voltage (V) and currents are basic values for the parameters of any electric circuit. However, the values of voltages are usually takes a high level so that values of voltage reach a danger dead level. Contrary, if the current is high, a heat effect will be introduced. This means that current transforms into heat while voltage transfers to a strike dead tension level. It sparks before burning while current only overheating a media. The used unit for measuring a voltage is Volt (V) as given in Table 6 –3 above.

3- Power

Power, in general, can be derived mathematical multiplication of both voltage and current with the effect of a power angle factor (ϕ) but it is known that the power can be one type of the three forms. The unit of measuring of each differs as specified as:

a) Active Power (P)

Active Power may be formulated as:

$$P = V \; I \; COS\;(\phi) \qquad (6-1)$$

It should be mentioned that Watt (W) is the unit of measuring as given in Table 6 – 3 above.

b) Reactive Power (Q)

It is the perpendicular component and it can be derived by:

$$P = V \; I \; SIN\;(\phi) \qquad (6-2)$$

The unit Volt Ampere Reactive (VAR) is the unit used as given in Table 6 –3.

c) Apparent Power (S)

It is the resultant value of both active and reactive power, then it is related according to the equation:

$$S^2 = P^2 + Q^2 \qquad (6-3)$$

The used unit is Volt Ampere (VA) as given in Table 6 – 3 .
It is remarkable that all their measurements depend on main parameters voltage and current as well as the angle.

4- Power Angle (ϕ)

It is the angle between vectors of voltage and current where the unit of radiant (rad) is used for measurement as given in Table 6 – 1.

5- Frequency (f)

The parameter frequency means the speed of synchronous generators in the power system where it is measured by (Hz). Its value may be 60 Hz as in Japan and USA or 50 Hz as Europe. It is known as the speed.

6- Energy (E)

It is known that energy can be calculated as:

$$\textbf{Energy} = \textbf{Power} \times \textbf{Time} \qquad (6-4)$$

The unit of energy in general is Joule unit (J) as listed before in Table 6 – 3 which means that it is based on the measure of current and voltage with the power angle in addition to the time unit (s).

7- Power Factor (p. f.)

It is a power factor which measures the percentage utilization of the

total power (Apparent Power). This factor is the major factor for electric companies around the world so that it takes more and more attention in the field. It is computed through the formula:

$$\text{Power Factor} = \cos(\phi) \qquad (6-5)$$

8- Impedance (Z) or Admittance (Y)

The value of any of impedance (with the unit (Ω) of measure as indicated above in the same chapter) or admittance (with the unit [mho] of measure, representing the mathematical reciprocal of impedance value or its unit) represents the ratio between voltage and current. Thus, only measurement for current and voltage should be required.

Both of these quantities are important to measure the distance from a fault because the measure of impedance or admittance gives the value till the point of fault. Thus, a quick determination for the place of fault can achieved immediately.

It is used for the distance protection although there is another advanced shape of this. It may be defined as a reactor characteristic in which the measured parameter will be the reactance instead of the impedance or the admittance.

III- Measuring Tools

It is seen that the measurement is always done by measuring instruments. This measurement is very necessary for some reasons where some of theses reasons may be indicated as:

1- Information technology and data base

It is important to record statistically the operation condition at steady state in order to get the way to improvement. Also, it is suitable to collect data about faulty conditions for the purpose of study and analysis. Therefore, it is highly recommended to put a statistical history for each element or even instrument in the united power networks. These collected data will help well in the advance of the operating conditions of station all over the world.

2- Reading

Instantaneous reading for some of the parameters inside a station may appear as a vital subject for engineers during the operation of a station. Then, a continuous reading may be required for many factors and parameters in a station. For example when a labor needs to go up a portal of a line, the responsible engineer should know that this place is out of tension. That is the line is out by CB inside a station but its situation at the other end in another station is unknown.

Then, a check should be found which can be found by the reading of voltage at this end of the line. There many cases that will be similar so that this reading principle must be generalized. Reading can be checked by measuring instruments as ammeters and voltmeters as well others.

3- Recording

Sometimes, the recording of a parameter help well in the analysis of a situation, specially if it is abnormal situation. This recording is required for many factors either always or in a stepped manner for other parameters. For example the load curve study depends to a great extend on the recoding concept for the power flow either of a line or a transformer or even for a station as a whole. Therefore, a recoding concept may confirm the best condition of work or the convenient way for operation of loading an equipment in the network. Then, all station put a restriction against ignoring this recoding.

On the other hand, recoding may be implemented in two methods such as automatically or manually. The automation in this procedure included in graphing either for power or current or even sometimes for power factor. The manual concept is widely used in terminal user stations where these stations are domestic or industrial.

4- Dispatching

Nowadays, dispatching centers depend on data based for all parameters and factors concerning all parts and stations in a united network.

This advanced shape of dispatching needs all values up to date in most cases so that the best solution for the continuous operation of a network. This can be needed for either temporary case or steady continuous one. Also, dispatching becomes un-central where dispatching process is tailored into some numbers of dispatching centers.

5- Control

All station in a power system depend on control style which must be automatically based. This control should act according to up to date values required for this control. Also, feedback may be a part of the control system so that up to date is a major factor for the good control systems. This control for example may be the control of synchronous speed or the bus voltage and so on. There are other types of control such as automated operation of switching processes through circuit breakers as well as the control against the wrong operation for some parts of a station.

6- Protection

It is one of the most important parts in the operation of electric power networks and then, Protection takes a great importance with each element inside a station. This may be appeared with all main equipment inside stations as alternators or transformers as well as lines and others. Protection is a very close item inside the subject of stations design.

This proposed concept of measurements for some or all of the parameters in stations may be implemented through some different engineering ways such as:

1- Direct Metering

This direct measure concept means the measure of the suitable values for measurements. This measures the currents at low currents (few Amperes) or voltage (up to many hundreds of volts) not more. It leads to the measure at low voltage low rating where the meter is inserted in the circuit in series for Ammeters or parallel for Voltmeters or both for kWh meters.

2- Tele-metering

The signal concept may be needed for the transmission of data through a large distance while transmission may be based on telephone circuits or even in a wireless style. It is convenient for dispatching centers for example.

3- Sampling

Sampling measuring means the measurement of a sample of the value. This means that a measure of 100 V is a sample for actual voltage of 100 kV where the sample ratio will be 1000 in this case. This logic measurement will be save because we can touch or catch the insulation of a wire 100 V. Contrary, no one can touch the insulation of a wire at 100 kV because it is a deadly touch. Similarly, the measure of 5 A is more practicable while it is impossible for 5 kA. The heat loss will be very high so that a melting condition for the circuit of measuring will be the situation.

On the other hand, the measured values of voltage and currents are high enough so that measuring tools may be transformer instruments. These transformers may be illustrated shortly in the next paragraphs.

1- Voltage Transformers

It is known that the power system contain different voltage levels from 220 / 400 V till 750 kV although we can not touch or even approach from such values of voltages. Then, a transfer concept in an exact manner may be applied. So, a transformation technique may be used in order to get a suitable non-danger values of voltages. This would be utilized by the use of voltage transformers.

As shown from the above mathematical equations that voltage in needed for measuring many parameters such as voltage, power, power angle, power factor, energy, and many others. This illustrates that the voltage transformer is a vital element of a station so that any station can not be installed without the presence of voltage or potential transformers. However with the raising in the voltage level, the potential transformer can not be used as a 3 phase potential transformer. It becomes a three individual transformers, each is a single phase voltage transformer.

Whatever, the potential transformer is needed not only for the measurement of many parameters and factors but also for the protection schemes in a station. Thus, the installation of a potential transformer for a certain action will increase the quantities of these transformers. Then, a single voltage transformer with a single primary winding and multi secondary windings will be the best solution. This will minimize the area required for installation with a complete action for all requirements (measurements and protections).

2- Current Transformers

Similarly, as it has been said for the voltage transformers, the current transformers would be based on the same logic style of that said above for the potential transformers. Then, a single current transformer with a single primary winding and multi secondary windings will be the best solution. This will minimize, too, the area required for installation with a complete action for all requirements (measurements and protections).
Current transformers differ from voltage transformers in many items of operation although the equivalent circuit for both is the same. Also, the in these equivalent circuits the output voltage in current transformers is very small while it is primary signal value in potential transformers. Current is also required for the measuring of current, power, energy as well many other parameters and factors. Otherwise, current transformers transfer the initial value of current into a small value where these values are standard. The nominal values of current transformers may be 1 , 2 and 5 A.
Both current transformers and voltage transformers are a fundamental measuring instruments in electric schemes of an electric station. The performance of each type of both acts as a nonlinear element in the electric circuit so that a great attention would be focused and illuminated on the operating points at normal and abnormal operations. The danger is concluded in the time and moments of a faulty conditions where the operating points on the characteristic curves can raised to be out the linear zone of characteristics.

6 - 2: DETECTION SYSTEMS

Detection is required in order to find the defect of a material or part of an equipment before happening or a detection can be reached to a good picture for an internal (un-shown) case. In general detection may be required in station for some reasons, almost danger cases, as:

1- Detection for fire beginning

2- Detection for the variation in a situation as (normal / abnormal) operations

3- Detection for the stranger interference

This may be analyzed as follows.

I- Fire Detection

Since a station contains many and different parts that have a great importance so that their protection may be a vital goal. Then, most of parts of a station may be subjected to a fire since the station works for and with electricity.
Therefore, a sensing system for the fire ignition would be designed for these stations in order to cut the way for the presence of any fire. Therefore, automatic sensors would be required where the basic standard main parameters are listed in Table 6 –6.

Table 6 –6: standard main parameters for detection systems

supply AC (V)	operation DC (V)	current mA	frequency Hz	Sensitivity db/m	signals
110/240	24	150	50 / 60	0.4 – 2.2	Sound/ flickering

1- Detection Systems

These parameters show that an operating voltage of about 24 V at DC is appeared but the system as a whole can be classified into 3 categories as:

a) Manual

It depends on the human and experience as well as it would be characterized at low importance. Its application is limited because it depends on the human experience.

b) Manual / Automatic

It is an integrated system and can cover the most cases of danger at low cost.

c) Automatic

It is the best system at all and hence, it is the recommended system for fire detection in stations.

Thus, a detection system has a standard units as indicated in Table 6 – 7.

Table 6 –7: Main Contents of detection systems

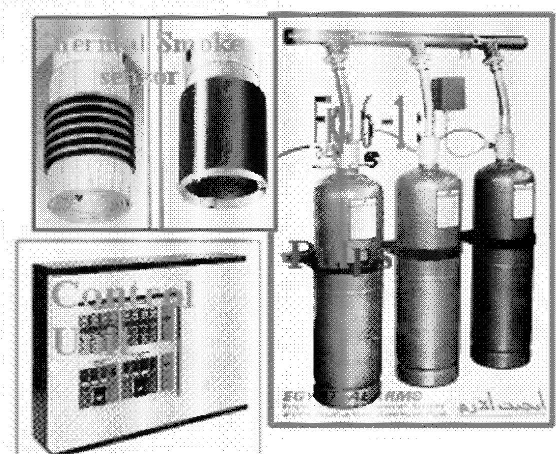
Title of unit	Specification
Control unit	It consists of a supply, a charger, & UPS unit. A control unit for each zone with all its connections. Then, it is connected to the central control unit.
Addressable processors	Routine revision & tests for circuits and all contents for check.
Data Communication	Receiving sent data to act sound / flickering signals & alarming.
Electric Connections	Connections inside an isolated pipes PVC at 24 V DC
Field Calling Points	It is installed at 1.4 m height with a span of 30 m spread for a specified area
Detectors	Many types

2- System Requirements

the main items that should be at least found for the application of complete fire fighting system may be abstracted as:

a) A lot of fire fighting pulps as shown for example in Fig. 6 – 1 where it consists of:

i- A pulp with standard volumes such as 1 , 3 , 5 or 10 liters where these units may be individual or multi unit system in order to cover the required area or volume at different situation. The optimal limit of badness may be the reference for a good engineering design.
ii- Control valve which controls the amount gas output from the pulp or pulps according to the system of operation for fire fighting. This valve must be checked periodically in order to face any emergency conditions.
iii- Ducts for use where the gas must go out to act on the fire. Then, all parts of the system must be checked in order to be ready for emergency.
iv- Sensor
It has many theories and types as well as various shapes with a varied standard for use. This will be abstracted below in order to put the main requirements in the front.
b) Spreading of ran ways for emergency
c) Automatic Sensors should be installed
d) Area partition for the emergency condition (with alarming and fire fighting).
e) Automatic communication with central team of fire fighting



f) Installation of a complete concept for fire fighting in all important parts of the station
g) Central control unit for fire fighting
h) Manual alarming points within the area (85 db)
i) Labor training for use
These systems may be installed for transformers or alternators or even for control rooms.

Table 6 –8: Smoke Sensors

Sensor	specification
Ionization	Sensible for smoke and generated gases to vary the measured ionization current, indicating about the presence of smoke inside the area. It covers a volume of 300 m^3 and good sensible before seeing a fire. Its integrated circuits should be protected from electronic interference.
Duct	Similar to the above one but it here determines the pre-value of gas presence. It is accurate and so it works directly with high speed alarming performance.
Optical	It has a photoelectric cell (infrared). It receives always the light in the sensor but scattering will occur with new gases. It covers 300 m^3 and suitable for PVC and others. It checks gases many times before alarming so that it prevents the false operation.
Beam	It is similar to the above one where gases change the situation at the photocell. Its beam length is 100 m but the distance between transmitter and receiver must not exceed 7 m. It can be installed at high heights (40m).

3- Sensor Types

There are many shapes as well as the systems of applications. Sensors based on different theories in order to face the situation automatically. These sensors may be used in factories or buildings or even indoor stations. Also, it can be installed for the indoor parts in the outdoor stations. Main group standard types of detectors that may tailored as:

a) Group of Smoke Sensors

Smoke detectors are the most spread types of all because of the low cost. It works well within all circumstances. The main characteristics for the different smoke detectors are abstracted in Table 6 –8 where their performance encourage a designer to be interested in for use. This type is statistically has a good repetition and acting well in all types of buildings. It is suitable for hotels, clubs, governmental buildings, sport halls and many others.

b) Group of Thermal Detectors

This group consists only of three types as specified in Table 6 – 9 where the best of them is the rate of rise of temperature sensor. It works with a time lag but its price is expensive relative to the others.

Table 6 – 9 : Thermal Detectors

Sensor	specification
Low Temperature	*It works at 58 C where the suitable height is 9 m*
High Temperature	It works at 88 C where the suitable height is 6 m
Rate of Rise of Temperature	It is the best. It depends on the high rate of rise of temperature representing a new thermal source. It works first with a signal then works at a specified time lag (if the rate is still increasing).

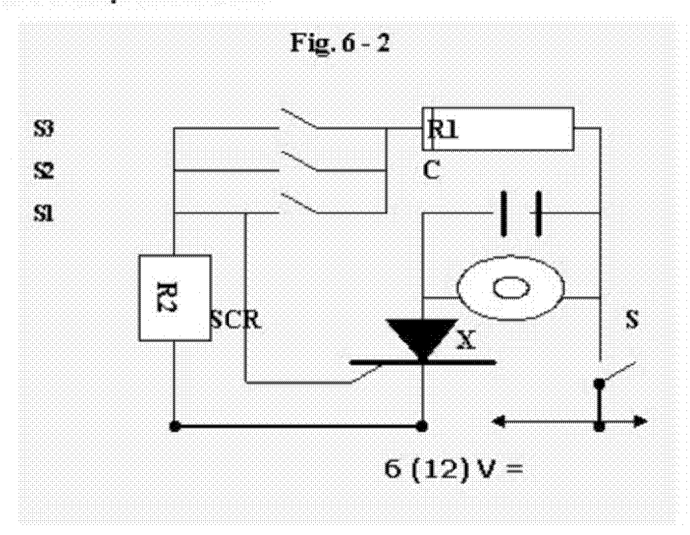
c) Group of Optical Detectors

These detectors are varied into three styles (Table 6 –10) where the optical sensors are generally characterized by the high level of sensitivity and accuracy.

Table 6 –10: The Optical Detectors

Sensor	Specification
Duct	It works with the distortion of a normal present beam in the sensor. It acts directly.
Flame	It depends on infrared rays in a limited area (25 m). A sensitive and accurate without false.
Beam	It acts automatically, installed at 25 m height, more sensitive with Gallium Arsenide at infrared rays.

II- Safety Detection



A safety technology must be applied in some parts of an electric station or sometimes in some stations such nuclear station. Then, a continuous revision for the places of danger would be ready in order to check the safety of the place under protection. A protected area can be covered according to the theory base of the safety concept used. It is generally based on electronic integrated circuits where different styles of circuits may be suitable while alarming system only is required. Therefore, a classification for the circuits used can be summarized as written below.

1- Opening doors or windows

This group of circuits depends on the variation action during opening a door where this title contains a lot of different circuits. Then, some all may be given shortly as:

a) Circuit 1

It works with a special battery 6 or 12 V through a main switch S while secondary parallel switches S_1, S_2, S_3 . Each secondary switch works with a certain door or window (Fig. 6 − 2). A switch should be closed (electrically) if a window (or door) is opened or moved. Resistances in the circuit can divide the potential of the source in order to supply a voltage on the thyristor. This leads to a ringing condition.

b) Circuit 2

The supply voltage for such a circuit is 9 V through a main switch S_1. In this circuit a flip flop with 2 gates N_1 , N_2 as a memory where a gate N_4 operates as a reflector (Fig. 6 − 3). Its output goes to a transistor TR_1 which opens or closes the circuit with a ringer BZ .There another micro switch S_2 as a protection on the door of a specified box or store for example. If switch S_1 is closed a condenser C_1 will be charged to generate output of N_3 at the high level H,(output of N_4 at the low level), then, transistor TR_1 prevents a ring BZ to operate. When the output N_4 becomes at a high level, the current will pass through resistance R_1 to diode D_1 .

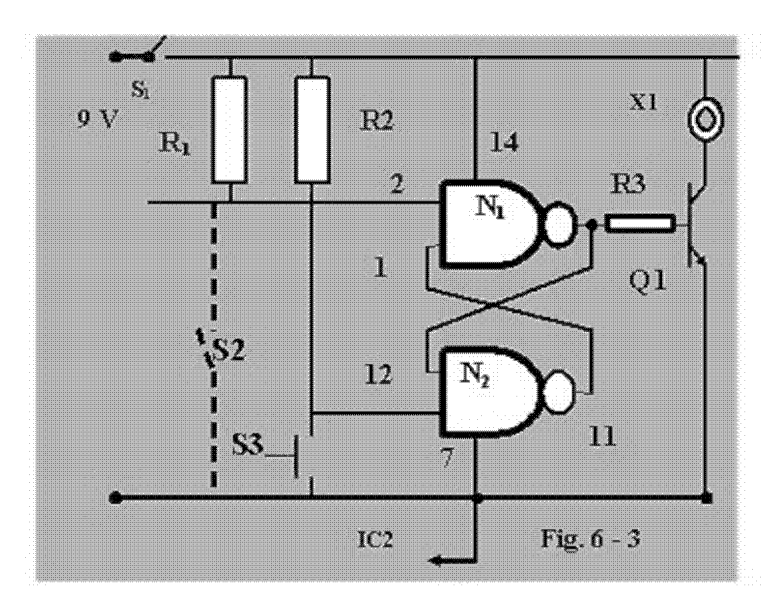


Fig. 6 - 3

c) Circuit 3

Group of switches (S_1- S_5) can be connected to doors or windows or a combination of them but the sum of resistances R_1:R_5 in the circuit may be about 50 k Ω. If the quantity of switches is raised, the series resistance must be reduced in order to get a resultant resistance of 50 k Ω . A starting setting must be adjusted by closing switches S_1-S_5 and a resistance P_1 can be controlled in order to stop the circuit action. Then, when the work ends an actuation for the circuit (S_6 is closed) would begin. This is shown in Fig. 6 – 4.

2- Broken windows

It is alarming circuit against the breaking of a window although this is important in counties at hard freezing weather as Canada and Russia. The weather is danger for life so that a protection for workers in such places should be considered.

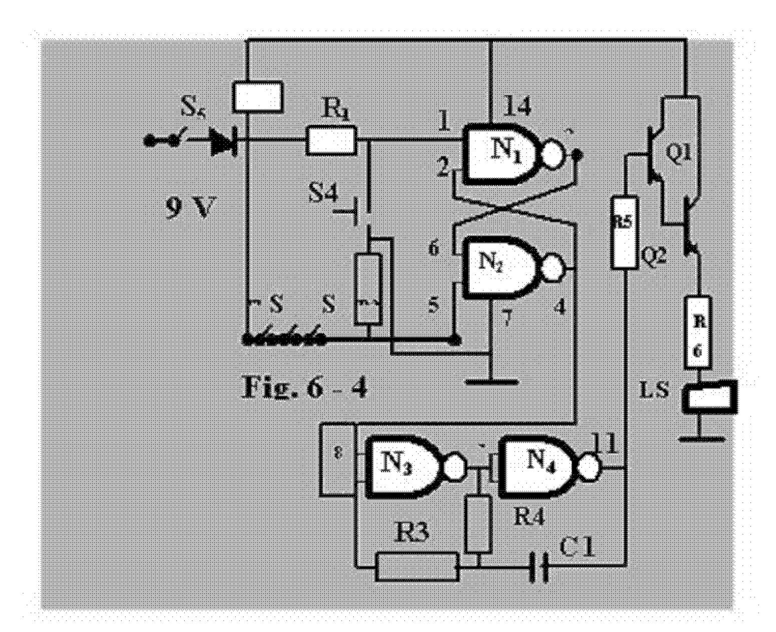


Fig. 6 - 4

3- Touch Alarming

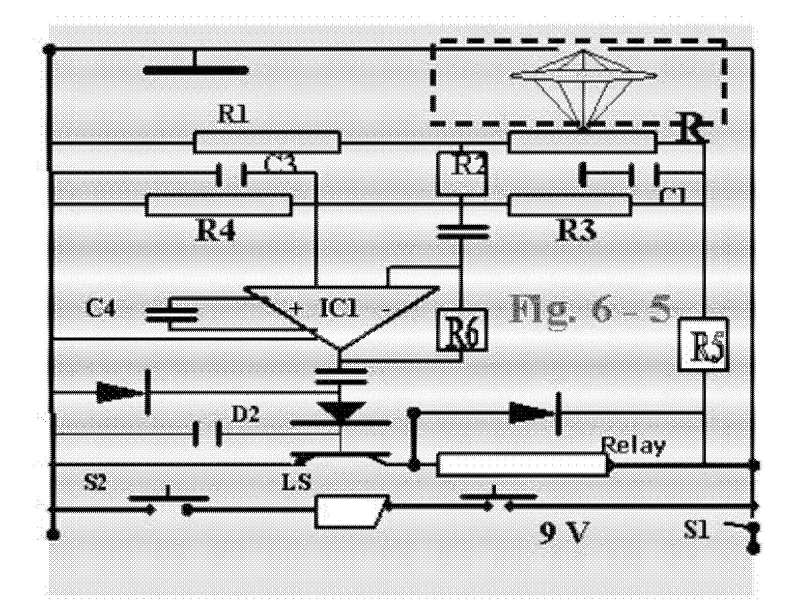
Touch technology is used in the electronic circuits for the purpose of safety where it can be installed in general in many important places. These place may be not only nuclear power stations but also many others such as, for example, military campus and safe sites in banks. Normally, the door touch may be the target as a first line of safety. This circuit has been drawn in Fig. 6 – 5 where a double rectifier silicon unit (D_4 and D_5) has been inserted with a smoothing condenser C_1 in the circuit.

A parallel resonance condition in this circuit may be generated according to the mathematical basic formula:

$$f = 1/ 2 \Pi ? LC \quad Hz \qquad (6 – 6)$$

When a switch S_1 is closed the oscillator works through the coupling

Then, the voltage V_C to be will be V_o decreased. This voltage will be appeared at the thyristor SCR to prevent any current through the ring. When a touch is occurred, C_4 will cause a current to the ring.



4- Crossing a volume

This concept is more advanced where it closes the volume for any strangers. There are many styles to fulfill such a technology. They may be indicated shortly next in order to explain the idea of safety in general inside a station.

A normal lighting circuit may be applied. Here the infrared rays has been used although two circuits are inserted in the scheme. These both circuits are transmitter and receiver where the frequency can be calculated by

$$F = 0.9 / (P_3 + R_3) C_2 \qquad \text{Hz} \qquad (6-7)$$

5- Optical Circuits

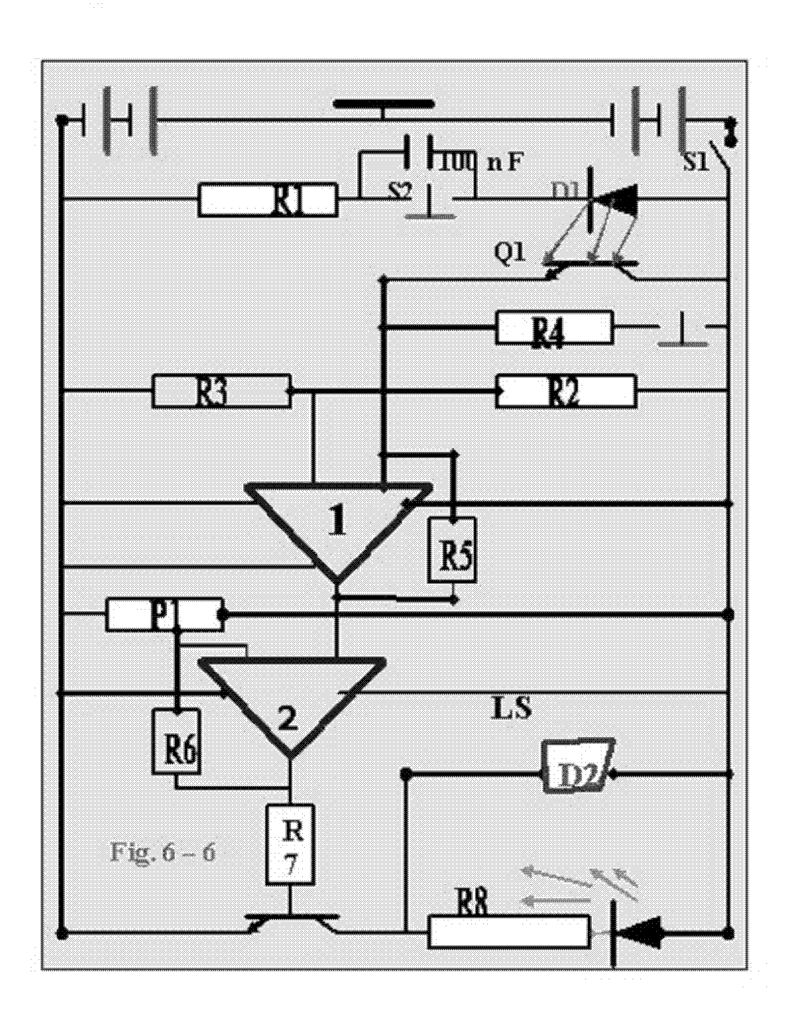


Fig. 6 – 6

This type of circuits is characterized by its high accuracy relative to all other types of circuits and then a circuit of (Fig. 6 – 6) is shown as example for this type of alarming circuits. There are many other types and styles for optical circuits such as optical refraction circuits or others.

6- Thermal Circuits

It is alarming circuit on the basis of thermal resistance effect as shown for example in Fig. 6 – 7. A resistance R_1, of a 47 kΩ, has a constant thermal factor (N.T.C) where a room temperature of 25 ̊C .

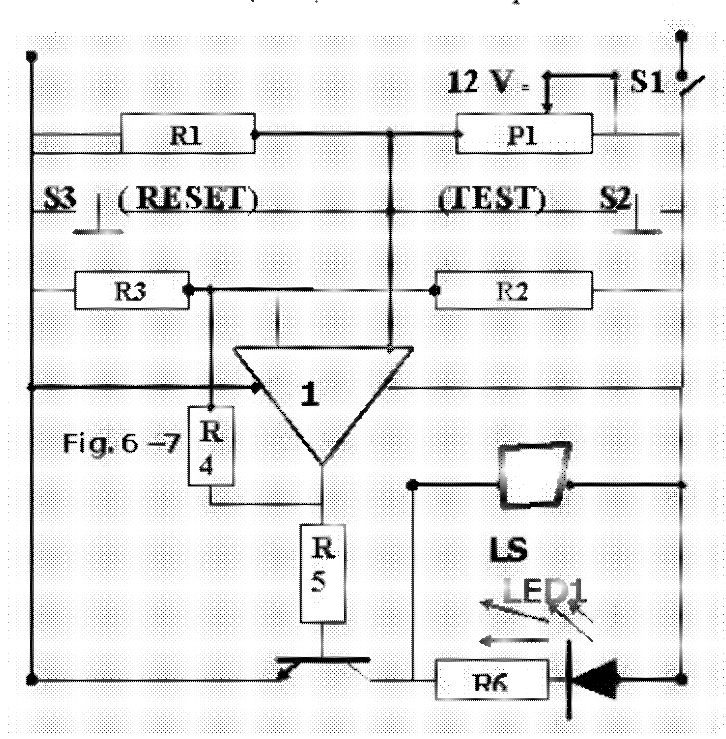


Fig. 6 –7

If a fire is started, the temperature will be increased where the value of a resistance R_1 will be reduced. This should occurred due to the negative resistance response (N.T.C) causing a signal creation in the alarm unit.

6 – 3: PERCEPTION

This item has its importance due to its characteristics which face the advanced technology in automation fields. Then, some of the axes may be illustrated shortly in order to explain the basics of the sensing and perception techniques.

1- Magnetic waves

Electromagnetic waves differ from caustic waves where has a long wavelength. The electromagnetic waves have shorter wave length but both of them are spread as waves as dawn in Fig. 6 - 8. This may be abstracted in Table 6 – 11 where the values of wave length are listed for different waves. This table present the sequence of waves with the main factors such as wave length , frequency and energy.

Table 6 - 11: Wave length of different waves

Radiation Type	Wavelength		frequency	Energy
	(Å)	(Cm)	(Hz)	(eV)
Radio	$> 10^9$	> 10	$< 3\times10^9$	$< 10^{-5}$
Short	10^9 - 10^6	$10 - 10^{-2}$	$3\times10^9 - 3\times10^{12}$	$10^{-5} - 10^{-2}$
Infrared	$10^6 - 7\times10^3$	$10^{-2} - 7\times10^{-5}$	$3\times10^{12} - 4.3\times10^{14}$	$10^{-2} - 2$
Visual	$7\times10^3 - 4\times10^3$	$7\times10^{-5} - 4\times10^{-5}$	$4.3\times10^{14} - .5\times10^{14}$	$2 - 3$
Ultraviolet	4×10^3 - 10	$4\times10^{-5} - 10^{-7}$	$7.5\times10^{14} - 3\times10^{17}$	$3 - 10^3$
X Rays	$10 - 10^{-1}$	$10^{-7} - 10^{-9}$	$3\times10^{17} - 3\times10^{19}$	$10^3 - 10^5$
Gama	$< 10^{-1}$	$< 10^{-9}$	$> 3\times10^{19}$	$> 10^5$

Results of data for waves as listed in Table 6 – 11 help well in filtering a ray from others where Fig. 6 –9 presents the principle of filtering according to Snel Law. The refracted angle would be varied with the change of the incident waves so that the filtering may be easy.

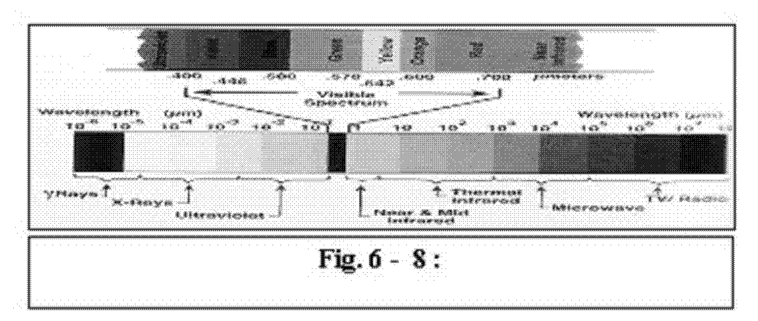
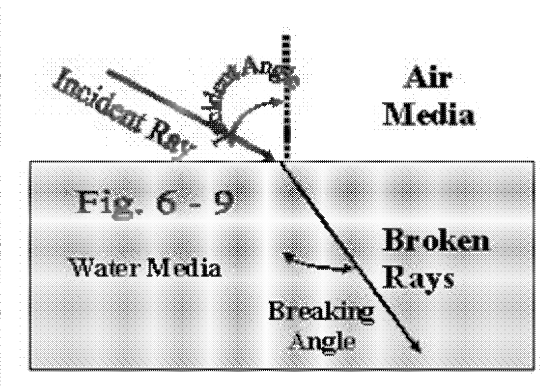


Fig. 6 - 8 :

2- Infrared Rays



These waves revolute the photo field in general that can take a picture without lights. This means an eye in the dark media where this eye can see every thing. This may be checked by the car picture given in Fig. 6 –10. It depends on the temperature of a body according to the (Stephan –Boltzman) equation for the value of emitted energy W with its absolute temperature of T:

$$W = \varepsilon\sigma T^4 \quad (6\text{-}8)$$

Where ε is the specific Emission value and σ is the Boltzman constant.

Infrared rays may be tailored in 3 categories as:

a) Far Infrared (Thermal)

It represents the microwave in the band of 3 – 30 micron where this ray may be created from sun or any hot body. The human senses this ray by neural system terminals at a skin. It may determine the difference between a skin temperature and the internal body temperature. These infrared rays (IR) are considered for applications in some fields. For example only, it is used in Medicine for the treatment of skin infections and muscles while it is used for metal and rubber painting in industry beside IR Line Scanner for thermal pictures. Otherwise, it is well applied for dark vision for its specific characteristics as:

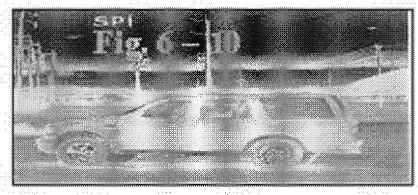


Fig. 6 – 10

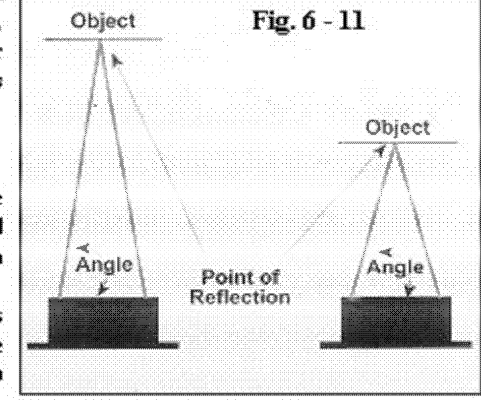


Fig. 6 - 11

i- Collecting of the body emitted infrared waves by a video camera.

ii- Direction of rays to a sensitive surface to get a Thermo-gram

iii- Transformation of thermal pictures into electronic pulses.

iv- Translation this into information data for Signal Processing Unit

v- Data transmission to a screen.

This type of vision is implemented in many fields as military and spaying as well for protection and alarming circuits.

b) Mid Infrared

This zone of infrared rays takes the wave lengths between 1.3 and 3 micron so that there is no thermal effect. Therefore, the human cannot be sensitive for it but it has a wide range of applications as for remote control systems.

c) Near Infrared

It is suitable for near control systems where it can be implemented for Robotic applications. It can be used as a sensor for control circuits because it has a band of 0.7 – 1.3 micron.

Table 6 – 12: Comparison of sonar and infrared sensors

Rays	Sonar	Infrared
Band (m)	0.41 – 10.5	0.04 -1.5
Accuracy Color sensation	High for = 40 cm Non-sensitive	High for = 24 cm Sensitive
Weather	Sensitive for sound speed change	Non-sensitive
Consumption Cost	= 100 – 200 mA High	= 30 – 250 mA Low

3- Infrared Sensors

Infrared Sensors can be successfully used as an approaching sensor with personal Robots because of the low cost for short distances (less than 25 cm). It can see the near bodies so that both infrared and sonar sensors are practicable as it is proved from the comparison between them as listed in Table 6 - 12. Hence, the application of Infrared Sensors is a positive performance so that the distance measurement is given in Fig. 6 – 11.

The angle of sensation is small (1.5°) so that it can be accurate determine the obstructed objects in the way in front. Also, the color reflects another effect on the measured values and consequently it is important to test periodically the sensitivity of such sensors.

4- Tracker Sensors

This sensor depends on transmitter / receiver base on the optical ray systems as indicated in Fig. 6 – 12 where a reference line is specified before work and then a relative determination would be realized. Otherwise, the components of such electronic circuits depending on tracker sensors may be collected in Table 6 – 13. It should be indicated that a certain tolerance may be permissible in order to determine the tracking target according to a specified value. These systems may be useful in nuclear power station with all accurate works and processes.

Table 6 – 13: Contents of tracker circuit

Part	Quantity	Part	Quantity
IR Photo transistor	3	High-output IR Emitter	3
Shrink Tubing		Small printed Circuit Board (PCB)	1
220 Ohm Resistor	3	Small Length of 1/4 " Φ Heat	3

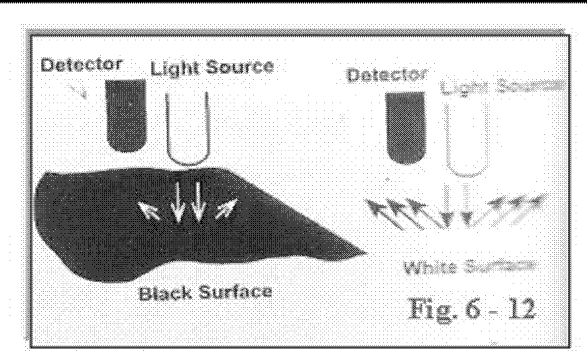
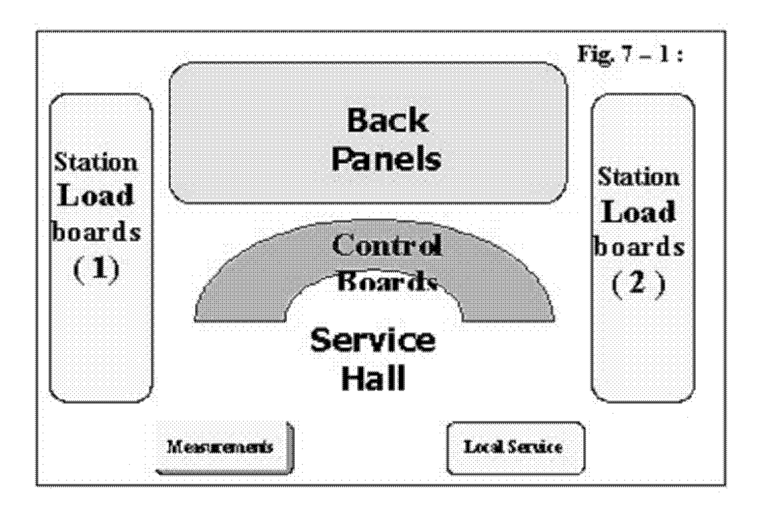


Fig. 6 - 12

FUNDAMENTAL AUXILIARIES

It is known that an electric station should be based on the main elements as well as on the attachments for theses main elements. So, it is important to investigate all main items inside the station as it has been explained in some details in the past chapter. Then, the most important requirements should be tailored in order to show the real necessary secondary components. Their role and the aim of presence would be a factor to be illustrated in the present chapter where these secondary elements are defined as auxiliaries.



7 - 1: SERVICE WIRING

Fundamental auxiliaries in power stations and substations include many and many titles such as fire fighting, water pumping, cooling systems, compressed air piping or gas piping and many others.

We would study the related direct items to the design of a station for examples as it is followed in the next lines. The auxiliaries in a station may be varied in a wide range of objects or types or even concepts however the main fundamental subject in concern may be the internal wiring inside. This wiring would be arranged so that it may be similar in its engineering base as well as the design requirements.

1- Control Room

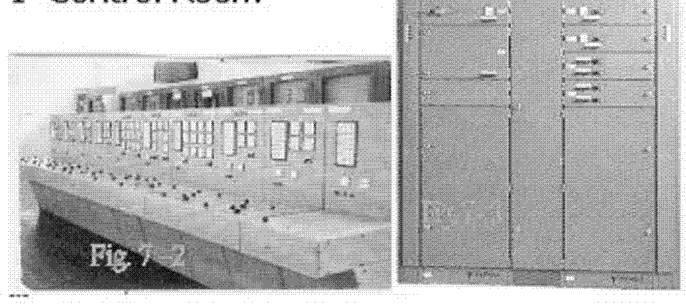


Fig. 7-2

Panel 1 cell 1	Panel 1 cell 2	Panel 1 cell 3	Panel 1 cell 4
Panel 2 cell 1	Panel 2 cell 2	Panel 2 cell 3	Panel 2 cell 4
Panel 3 cell 1	Panel 3 cell 2	Panel 3 cell 3	Panel 3 cell 4

Fig. 7 – 4 :

The control room can be considered as the vital point in a station as a result to the possibility for operation inside the control room. This control room controls the processes of switching and determination of the positions of occurred faults or any abnormal operation inside. The critical cases may be indicated also inside as well as the treatment for a faulty condition occurred. It consists of a main panel or some panels as illustrated in Fig. 7 - 1 where Fig. 7 – 1 gives a simple sketch hand for one of the possible general view for the distributions of the panels inside the room.

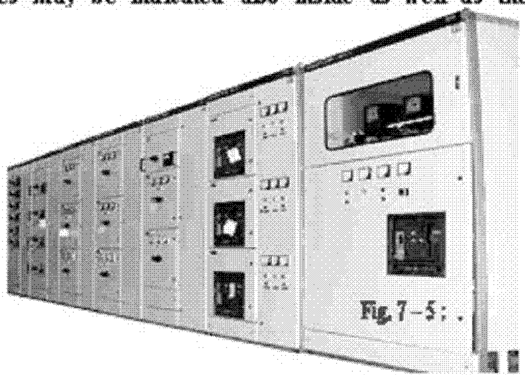


Fig. 7 – 5 : .

In the figure the sub-panels are given in the behind of the main panel. On the other hand, a typical picture for the control room secondary panel (as load panel (1) or (2)) is given in Fig. 7 –2. This is not the only shape for such side but it is a sample for illustration.

A panel zone consists of many small panel where they are arranges in a similar way to the parts of the station (similarity concept). Each of these panels treats a certain cell (or a part of it as given in Fig. 7 - 3) in the site outdoor or indoor. The presented pictures are given for a 3 – D imagine in order to evaluate the space in a station as well as area. Also, a method for arrangement may be considered all other related small items. This board is an original unit by which all contents of the control room consists of.

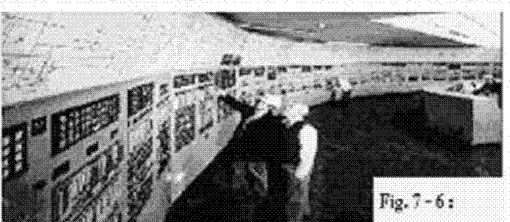


Fig. 7 - 6 :

Thus, the Back panel section of a control room may be arranged in order to simulate the distribution of all contents in a station. It may be divided in a block style system as indicated in Fig. 7 – 4. This drawn plan may be for the back site in a control room or a part in it. The concept of arrangement is simple and easy to understand so that no way for mistakes. Then a single cell panels are arranged as shown in Fig. 7 – 5. This explains the reason for plan drawings before.

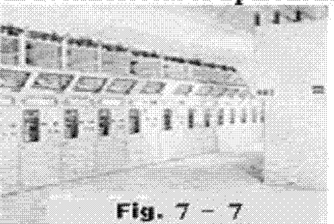


Fig. 7 – 7

The most important picture for the front part of a control room may be shown in Fig. 7 – 6 where the control panel board are arranged together according to the single line diagram of a station. However, the panel components will a part of this single line diagram while the points of CB on it will be real switches for the original CB. This means that this part of a station should be a secret zone for strangers in order to prevent any false switching action. Then, similarly the back of the control room may take a similar shape as given in Fig. 7 – 7 for example. This helps well the designers and engineers in general.

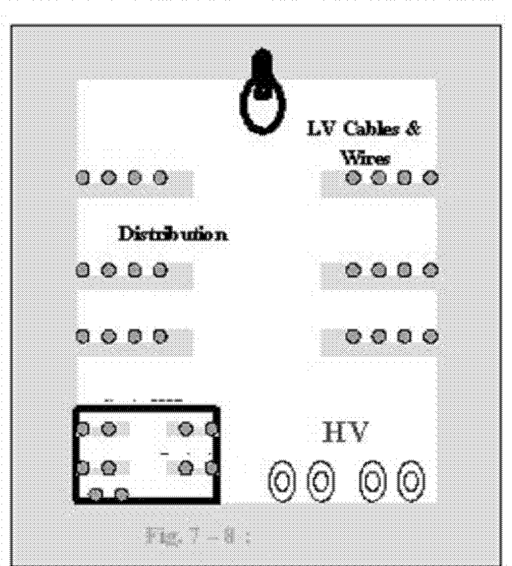


Fig. 7 – 8 :

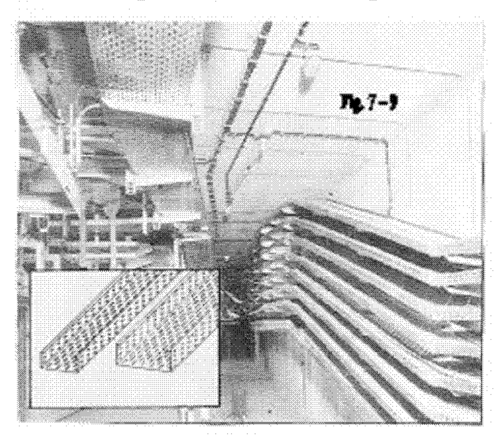
The remainder parts that in the front of the single line diagram panels will be that of measuring instruments in the station and that for the DC supply part. The measuring panels may contain Ammeters, voltmeters witch selector switches, oscilloscopes, oscillographs and power meters, ... They may have the sub-main control panels. It should be said that the computerized systems may vary such a shape however it may take an advanced other shapes for the control room as a whole (not only for the panel collection). The other one will have the single line diagram for the DC station inside the station itself.

The control room is established in order that the shift engineer can easily check the situation of the station in all its parts. Then, all needed instruments as well as readers would be inserted inside so that it must contain some different items. The most important of them may be recorded next within the presented chapter.

2- Secondary Wiring

Secondary conductors are the elements of either the control circuits or the protective schemes. They are the heart of the secondary circuits for a station such that any fault in the wire may cause a damage for the station or any part of it. Consequentially, the method of wiring must be done according to the international specifications. This means that the wiring system should be implemented through underground tunnels (See Fig. 7 -8).

The supporting arms takes a conductor as specified with quantity and diameter.



Each type of circuits must be avoided from interference with others as illustrated in the figure.
The light weight conductors may be above as well as a lighting lamps should be installed in order to cover the processes of wiring as the maintenance. The control wiring as well as the protection wiring must be far located from HV cables so that their supporting arms may be thin and lighter as shown in Fig. 7 – 9.
It is important to indicate that the lighting either the normal or the emergency lights must be installed in such tunnels because a maintenance may be needed. Also, lights are necessary for good vision that may raise the level of quality of labor during work. Thus an arrangement is required as done for the control room according to the basics of design (chapter 1 of the present book). Then, all of connection and the distance between supports inside a tunnel must be installed on the basis of international specifications.

3- Signaling Concept

The goal of control room tends to be mainly for the operation of a station without mistakes so that the deviation out of the normal operation must be indicated immediately. This means that the situation of the station totally as well as individually would be recognized by engineers inside this control room. Therefore, it is very required to inform engineers in the control room about any deviation or even any change in the normal situation of operation. This can be implemented according to the principle of signaling and alarming concept.

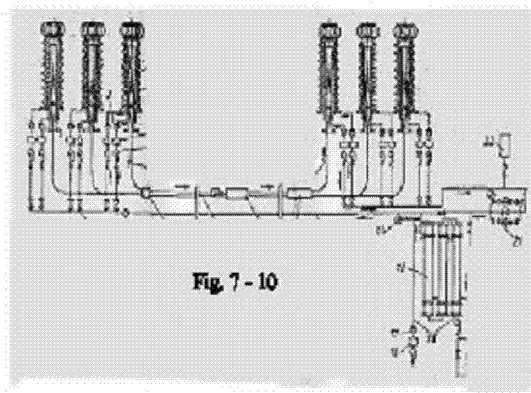


Fig. 7 - 10

Signaling can be divided into two types inside the control room as a main signal on the single line diagram panel with a secondary type of signal. The secondary type of signaling may be varied according to the type of fault or mistake or if it is a stage inside a technical operation for switching in the power network.

4- Pumping Stations

One of the most rarely cases is shown in Fig. 7 - 10 where the cable oil pumping system is given. This figure illustrates the importance of insulation inside bushing although it is a small part. The pressure of the cable oil inside the bushing is defined so that a minimum value for the pressure should be signaled. The system is shown in the figure well. This system may be implemented for individual bushing or for multi bushing system. Also, it can be a pumping system for HV oil cables.

Therefore, such system can be done for the piping of compressed air to supply the air blast circuit breakers. In stations with power transformers where the insulation is the transformer oil, a pumping system for this oil should required. This is done through the cooling system for the oil transformers. Also, there is another system of pumping such as water pumping although for thermal power stations a pumping system will be needed for the liquid fuel circulation or transportation. In general pumps are the most type of loads in electric stations.

5- Cooling and conditioning

Since a control room is the head of operations in the station, a cooling or ventilation or conditioning system will be a major target for the high quality operation in a station. Accordingly, a main load in a station would be the motors for such systems. It may be an original factor for the circuits of either control or protection. Then, a good managing work can minimize the false operations in the station since the operating point of electronic circuits is always depending on the room temperature.

7 - 2: ECONOMIC OPERATION

Economic operation is a very important tendency for any power system to return a self profit on the capital. This is fixed by regulatory paddies and the importance of conservation of fuel place pressure on power companies (As the present situation in Egypt) in order to achieve maximum possible efficiency. This maximum efficiency will minimize the cost of energy in KWH received to a consumer and the cost to the company of delivering that KWH in the face of constantly rising prices for running cost such as fuel, labor, supplies, maintenance and others.

Operational economics involving power generation and delivery can be divided as economic dispatch and the energy loss. At a specified load dispatch center determines the power output of each plant which minimizes the overall cost of fuel consumed to serve the system load as a coordination of the production costs at all power. This can be done through the control of power flow to be minimum. This gives the meaning of importance of the good design of the single line diagram as well as the layout as discussed above.

The optimal power flow can be viewed as a sequence of conventional Newton Raphson power flow method, in which certain controllable parameters are automatically adjusted to that satisfy the network constraints while minimizing a specified objective function. It depends on the economic distribution of the output of a plant between the generators or units within it. This, also, can be applied to economic scheduling of the plant outputs for a given loading of the system without consideration of transmission losses. These losses are a function of the outputs of the various plants so that the output of each of the plants of a system is scheduled in order to achieve the minimum cost of power delivered to the load terminal.

Coordinated control of the power plant out puts is a necessary to ensure generation to load balance so that the system frequency will remain as close as possible to the nominal operating value, usually 50 or 60 Hz . Accordingly, the problem of automatic generation control (AGC) is developed from the steady state viewpoint due to the daily load variation so that the utility has to decide on the basis of economics which generators to either start up or shut down.

The computational procedure for making such decisions is called unit commitment.

I- Load Distribution within a plant

An early attempt at economic dispatch called for supplying power from only the most efficient plant at light loads. As load increased, power would be supplied by the most efficient plant until the point of maximum efficiency of the plant was reached then, for further increase in load the next most efficient plant would start to feed power the system and third plant would not be called upon until the point of maximum efficiency of the second plant was reached (even with transmission losses neglected). This method fails to minimize cost. The economic distribution of a load between the various generating units inside a station (consisting the costs of a turbine and generator operations, and the steam supply) should be realized. The variable operating costs of a unit must be expressed in terms of the power output where the fuel cost is the principal factor in fossil – fuel plants. Also, the cost of nuclear fuel can be expressed as a function of output.

This discussion is based on the economics of fuel cost with the realization that other costs which are a function of power output can be included in the expression for fuel cost a typical input -output curve which is a plot of fuel input for a fossil- fuel plant in British thermal units (BTU/H) versus power output of the unit in MW.

The ordinates of this relationship are converted to dollars per hour by multiplying the fuel input by the cost of fuel in dollars per million BTU. If a line is drawn through the origin to any point on the input – output curve, the slope can be expressed in millions of BTU/H divided by the output in MW, or the ratio of fuel input (BTU) to energy output in MWH. This ratio is called the heat rate and its reciprocal is the fuel efficiency. The lower heat rates imply higher fuel efficiency where maximum fuel efficiency occurs at that point where the slope of the line from the origin to a point on the curve is a minimum, that is, at the point where the line is tangent to the curve.

The fuel requirement for a given output is easily converted into dollars per MWH. The criterion for distribution of a load between any two units inside the station is based on whether increasing the load on one unit as the load is decreased on the other unit by the same amount results in an increase or decrease in total cost. This incremental fuel cost is determined by the slopes of the input – output curves of the two units. If we express the ordinates of the input – output curve in $/H and let:

$$F_i = \text{input to unit number (i), (\$/H)}$$
$$P_{gi} = \text{output of unit number (i), (MW)} \quad (7-1)$$

The incremental fuel cost of the unit in dollars per megawatt hour is dF/dp_{gi}, whereas the average fuel cost in the same units is F_i/P_{gi}. If the input –output curve of unit (i) is quadratic, and then the unit has

$$F_i=(a_i ? 2)\times P_{gi}^2+b_i \times P_{gi} + C_i \ \$/H \quad (7-2)$$

incremental fuel cost denoted by λ (i), which is defined by

$$\lambda_i=dF_i/dP_{gi}=a_i \times P_{gi}+b_i \ \$/MWH \quad (7-3)$$

where a_i, b_i and c_i are constants. The approximate incremental fuel cost at any particular out put is the additional cost in $/H to increase the output by one MW. Actually, incremental cost is determined by measuring the slope of the input – output curve and multiplying by cost per BTU in the proper units. A typical plot of incremental fuel cost versus power output can be technically approximated to a straight line without any loss in the accuracy. In analytical works, the curve is usually approximated by one or two straight lines. The equation of this line is defined by

$$\lambda_i = dF_i/dP_{gi} = 0.0126P_{gi} + 8.9 \quad (7-4)$$

For more accuracy, two straight lines (not one) may be drawn to represent this curve in this upper and lower range.

$$\lambda = df_1/dP(g_1) = a1 \times P(g_1) + b_1$$

$$\lambda = df_2/dp(g_2) = a_2 \times P(g_2) + b_2 \quad (7\text{-}5)$$

All the above lines give the background to understand the principle of economic dispatch which guides distribution of load among the units within one or more plants of the system. For instance, suppose that the total output of particular plant is supplied by two units and that the division of load between these units is such that the incremental fuel cost of one is higher than that of the other. Then, suppose that some of the load is transferred from the unit with the high incremental cost to the unit with the lower incremental cost. Reducing the load in the unit with the higher incremental cost will result in a greater reduction of cost than the increase in cost for adding the same amount of load to the unit with the lower incremental cost. The transfer of load from one to the other can be continued with a reduction in total fuel cost unit the incremental fuel costs of the to units are equal. The same reasoning can be extended to a plant with more than two units. This economic view can be reflected on the layout design of a station in order to simplify the process of adding fuels to the boilers.
Thus, for economical division of load between units within a plant, the criterion is that all units must operate at the same incremental fuel cost. When the incremental fuel cost of each of the units in a plant is nearly linear with respect to power output over a range of operation under consideration, equations that represent incremental fuel cost as linear functions of power output will simplify the computations.
An economic dispatch schedule for assigning loads to each unit in a plant can be prepared in steps :

1- Assuming various values of total plant output.
2- Calculating the corresponding incremental fuel cost (λ) of a plant.

3- Substituting the value of (λ) for (λ_i) in the equation for the incremental fuel cost of each unit to calculate its output.

Thus, a curve for (λ) versus plant load establishes the value of (λ) at which each unit should operate for a given total plant load. For a plant with two units operating under economic load distribution the(λ) of the plant equals (λ_i) of each plant, and so solving for $P(g_1)$ and $P(g_2)$, we get

$$P(g_1) = (\lambda - b_1) / a_1$$

$$P(g_2) = (\lambda - b_2) / a_2 \qquad (7-6)$$

Then, the required total power of the load may be estimated in the form

$$P(load) = P(g_1)+P(g_2) \qquad (7-7)$$

The savings effected by economic distribution of load rather than some arbitrary distribution can be found by integrating the expression for incremental fuel cost and by comparing (increase/ decrease) case of cost for the units as load is shifted from the most economical allocation. This will facilitate the processes of calculations and thus, the processes of switching of the cells of a certain units can be ready in advance.

II- unit commitment

Because the total load of the power system varies throughout the day and reaches a different peak value from one day to another (The daily load curve), the electric utility has to decide in advance which generator to start up and when to connect them to the network-and the sequence in which the operating units should be shut down and for how long. The computational procedure for making such decisions is called *unit commitment*, and a unit when scheduled for connection to the system is said to be *committed*. Therefore, the commitment of fossil-fuel units which have different production costs because of their dissimilar efficiencies, designs, and fuel types should be considered. Although there are many other factors of practical significance which determine when units are scheduled (ON/OFF) to satisfy the operating needs of the system, economics of operation is of major importance.

Unlike on line economic dispatch which economically distributes the actual system load as it arises to the various units already on line, unit commitment plans for the best set of units to be available to supply the predicted or forecast load of the system over a future time period.

To develop the concept of unit commitment, we consider the problem of scheduling fossil-fired thermal units in which the aggregate costs(such as start-up costs, operating fuel costs, and shut –down costs)are to be minimized over a daily load cycle. The underlying principles are more easily explained if we disregard transmission loss in the system. Without losses , the transmission network is equivalent to a single plant bus to which all generators and all loads are connected, and the total plant output P_{gt} , then equals the total system load P(D). The 24-h a day can divided into discrete *interval* **or** *stage* **and the predicted load of the system will be considered constant over each interval.**

The unit commitment procedure then search for the most economic *feasible combination* **of generated units to serve the forecast load of a system at each stage of the load cycle. The power system with k generating units (no two identical) must have at least one unit on-line to supply the system load which is never zero over the daily load cycle. If each unit can be considered either** *on*(**denoted by 1)or** *off* **(denoted by 0), there are 2^{K-1} candidate combinations to be examined in each stage of the study period. For example, if k = 4, the 15 theoretically possible combinations for each interval are combinations (See Table 7 - 1).**

Table 7 - 1: The theoretically possible combinations

Unit	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}
1	1	1	1	1	0	0	1	0	1	1	0	1	0	0	0
2	1	1	1	0	1	1	0	0	1	0	1	0	1	0	0
3	1	1	0	1	1	0	0	1	0	1	1	0	0	1	0
4	1	0	1	1	1	1	1	1	0	0	0	0	0	0	1

In this table X_i denotes the combination *I* of the four units. Of course, all combinations are not feasible because of the constraints imposed by the load level and other practical operating requirements of the station according to the single line diagram and its layout or of the system itself. For example, a combination of units of total capability less than 1400 MW can not serve a load of 1400 MW or greater, any such combination is *infeasible* and can be disregarded over any time interval in which that level of load occurs. The mathematical formulation of the unit commitment problem may be taken the assumption that the combination X_i of interval k is X_i (k) and so X_j(k+1) represents combination X_j of interval (k+1). If k equals 1 and i equals 9 in the four – unit example above, the combination $X_9(1)$ means that only units 1and 2 are on – line during the first interval.

The production cost incurred in supplying power over any interval of the daily load cycle depends on which combination of units is on –line during that interval. For a given combination X_j the minimum production cost P_j equals the sum of the economic dispatch costs of the individual units. Accordingly, we designate that P_j(k) will be equal to the minimum production cost of combination X_j(k) and then P_j (k+1) would be the minimum production cost of combination X_j (k+1). Also *a transition cost*, which is the cost associated with changing from one combination of power – producing units to another combination should be considered. Usually, a fixed cost is assigned to shut down a unit, which has been operating on the system, since *shut-down* cost is generally independent of the length of time it has been running. However, in practical situations the *start-up* cost of a unit depends on how long the unit has been shut down from previous operation (Refer to the lay out of the cell concerned).

This is to be expected since the boiler temperature of the unit and fuel required. The fuel is needed to restore operating temperature depending on the duration of cooling. Assuming a fixed start-up cost for each unit and referring the reader to other practical consideration and then, transition cost T_{ij}(k) associated with changing from one combination of operating units X_i (k) to another X_i (k+1) will have fixed start-up and shut down components denoted (from interval k to interval k+1).

If each unit could be started up or shut down without incurring any transition cost, then from the economic viewpoint the problem of scheduling units to operate in any one hour would become disjoint from and totally unrelated to the scheduling problem in any other hour of the load cycle. On the other hand, suppose that it costs $ 1500 to shut down a unit and $ 3000 for each unit start up then, to change from combination $X_2(k)$ to combination X_3 (k+1) to the above four unit example, the transition cost $T_{2,3}(k)$ becomes ($1500+$3000) =$4500 because unit 3 is to shut down and unit 4 is to start up at the beginning of interval (k+1). Furthermore, the status of units in interval (k+1) affects the transition cost to interval (k+2),and so on.
Therefore, transition cost links the scheduling decision of any one interval to the scheduling. Decisions of all the other intervals of the load cycle. Accordingly, the problem of minimizing costs at one stage is tied to the combinations of units chosen for all the other stages, and we say that unit commitment is a *multistage* or *dynamic* cost-minimization problem. The dynamic nature of unit the commitment complicates its solution. Suppose that 10 units are available for scheduling within any one-hour interval, which is not unlikely in practice. Then, theoretically a total of $2^{10-1}=1023$ combinations can be listed. If it were possible to link each prospective combination of any hour to each prospective combination of the next hour of the day, the total number of candidate combinations becomes $(1023)^{24} = 1.726 \times 10^{72}$, which is enormously large and unrealistic to handle. Fortunately, however, the multistage decision process of the unit commitment problem can be dimensionally reduced by practical constraints of system operations and by a search procedure based on the following.
The daily schedule has N discrete time interval or stages, the durations of which are not necessarily equal. Stage 1 precedes stage 2, and so on to the final stage N. A decision must be made for each stage K regarding which particular combination of units to operate during that stage. This is the stage K sub-problem. In order to solve the problem for the N decisions, N sub-problems should be solved sequentially in such a way (called the *principle of optimality*) that the combined best decisions for the N sub-problems yield the best overall solution for the original problem.

This strategy greatly reduces the amount of computation to solve the original unit commitment problem, then the cost may be expressed as

$$F_{ij}(k) = P_i(k) + T_{ij}(k) \qquad (7\text{-}8)$$

Which is the combined transition and production cost incurred by combination X_i during interval K plus the transition cost to combination X_j of the next interval. For ease of explanation it is assumed that the system load levels at the beginning and of the day are the same. Consequently, it is reasonable to expect that the state of the system is the same at the beginning and at the end of the day. Therefore, at K=N the transition cost T_{ij} (N) becomes zero where the cost F_{ij} (k) is tied by T_{ij} (k) to the decision of the next stage (k+1). In order to know the *best policy* or set of decisions (in the sense of minimum cost) over the first (N-1) stages of the daily load cycle, it is assumed that the best combination of the units for each of the first(N-1) intervals is chosen. If this combination X_i is the best combination for stage (N-1), then, by searching among all the feasible combinations X_j of the final stage N, then minimum cumulative cost of the final two stage starting with combination X_i (N-1) and ending with combinations X_j(N) may be formulated as

$$F_i\,(N\text{-}1) = \min\,\{P_i\,(N\text{-}1) + T_{ij}\,(N\text{-}1) + F_j(N)\}\,\{X_j(N)\} \qquad (7\text{-}9)$$

where the cumulative cost F_j(N) of stage N equals the production cost P_j (N) since there is no further transition cost involved. This means that the search for the minimum-cost decision is made over all feasible combination X_j at stage N. Consequentially, we do not yet know which combination is X_{i*} (N-1). For each possible starting combination X_i (N-1), it is straight forward to solve for the best stage-N decision. This will store the corresponding minimum-cost results in a table for later retrieval when the best combination X_i (N-1) has been identified.

Similarly, starting with the combination Xi(N-2) at interval (N-2), the minimum cumulative cost of *final three* stages of the study period is given by

$$F_i\ (N-2) = \min \{ P_i(N-2) + T_{ij}\ (N-2) + F_i(N-1)\}\{X_j(N-1)\} \qquad (7-10)$$

where the search is now made among the feasible combinations X_j of stage (N-1).
Continuing the above logic, the recursive formula may be

$$F_i(k)=\min\{P_i(k)+T_{ij}(k)+F_j(K+1)\}\{X_j(K+1)\} \qquad (7-11)$$

For the minimum cumulative cost at stage K, where K ranges from 1 to N. According to the reasons stated earlier, it is required to reach the state being the same at the beginning and at the end of the day when K equals N in the last equation. When K equals 1, the combination X_i (1) is the known initial condition input to the unit commitment problem. The combinations corresponding to subscripts i* and j change roles from one stage to the next; the combination $X_{i^*}(k)$, which initiates one search among the feasible combinations X_j (K+1), becomes one of the feasible combinations $X_j(k)$ which enter into all searches of stage (K-1).
This brief section is a good manner to help us in the subject of design of each generating cell in the layout as well as the importance of minimizing the loss across the conductors and all components in the cell. Thus the design of the single line diagram of a station would be a best one with the minimum loss and high reliable. Also, the study of the load curve appears to be a basic item in the given design.

7 – 3: STORES

Storing means a collection for all equipment and all spare parts for a station in a certain place in order to get any required component at any time periodically or at emergency conditions. The process of storing must save any part against any external effect and it must be protected from any defects. The planning of a store means the engineering and economic concepts for the determination of place, area, type, facilities that can achieve the goal for the job of stores inside a station. Visibility study may be the direct way for such a problem either for short or long terms.

I- Actuating Factors

These factors may be the most affecting parameters in the design of a store or stores in a station as they can be abstracted in the form:

1- Characteristics of stored matters: weight, size, type, corresponding services.
2- Simplicity for receiving and transferring either externally or internally.
3- Efficient division for the area.
4- Optimal classification of stored objects.
5- Good technical distribution for contents.
6- Optimal movement for each type inside.

II- Requirements

This also, may achieve a lot of restrictions and requirements as:

1- Good transportation and both casers of charging or discharging.
2- Good lifting tools.
3- Control the humidity within the permissible limits
4- Protection against temperature rise
5- Good arrangement and classification for the parts inside the store
6- The choice of store type
7- The choice of suitable location
8- Simple design of the internal layout of the store.
9- The necessity for simple documental process.
10- Continuous Labor training.

11- Visibility study for the design of stores in a station.
12- Supervision for the store performance during work.
13- Good enveloping.

III - Store contents

This stored material may vary in a wide range either for the material structure or the material content of its physical and chemical characteristics. Then, a stored material may be classified as:

1- Raw material.
2- Internal semi manufactured material.
3- Ready manufactured material.
4- Half manufactured material.
5- Auxiliary material.
6- Rejected material.
7- Damaged material.
8- Spare parts.
9- Tools.
10- Instruments.
11- Machines and engines
12- Liquids.
13- Gases.
14- Equipment
15- Scraps.

Whatever, the great variety of the stored objects may cause a high level of information to bring the action of storing to the highest possible efficiency. This requires some items of specification of each as written below:

1- State
2- Shape, weight, dimensions.
3- Chemical and physical characteristics.
4- Concept of storing.
5- Effect of temperature, humidity, sun light, mechanical vibrations, sudden impacts, weather.

6- Quantity and type.

IV- Target of Storing

Storing title is an important factor for the reliability of a power system operation although this may not be illuminated before. Otherwise, storing a spare part may consume a place inside a station but it will save effort and time during emergency situations. Storing spare parts will achieve some vital strategy operation for the network as a whole. This means that if we have not this part inside the station - if it is needed – we will loss a time as well as we will consume an effort to find it. This is a defect in the engineering level so that stores must be a part of the station design. Thus, the most important factors for the necessity of the store presence may be summarized in the following points.

1- Safety of stored objects against defect or loss.
2- Checking for the standard specifications.
3- Accurate and safe storing.
4- Continuous presence for all parts which may be 5- needed in the station during operation.
6- Minimizing the storing cost.

IV- Planning of Storing

This item may be abstracted in axes as will be developed in the following paragraphs.

1- Data Base

The information facility appears to be the first important factor for optimal operation and utilization of a store in a station. This goal may record the information for all the following items and points:

> **a) Number technical or engineering unites (and their sites) inside a station that will be served by this store.**
>
> **b) Number of other stations (and their sites) must be in circle of service.**

c) Technical classification for contents as for:

i- Size : small, big, very small and very big.
ii-Weight: light. normal, medium, heavy, very heavy
iii- Solid state: Gas, liquid, solid

These types may be subdivided as:

i-Enveloped in boxes or bottles or containers
ii-Non- Enveloped

Each of all can be again classified inside the above division as:

i-Indoor storing such as very small objects that cannot be subjected to the sun light.
ii-Outdoor storing such as a HV cables or Big power transformers.

d) The shelf needs
e) Special requirements
f) Tools of lifting and transporting
g) Labor quality

Thus, the number of stores in a station can be evaluated and then their suitable individual and total area.

2- Area

However, some external rules may influence in the final selection but it must depend on the engineering level. Then, the derived area of a store may take into consideration the following parameters:

a) Future extension.
b) Distance from the public transportation.
c) Infrastructure facility.
d) Labor quality
e) The possible effect of political and economical variations on the location.

f) Engineering security and safety against fire, surges, floods, stolen cases.
g) Possibility of natural disasters appearance.
h) Schedule of implementation.

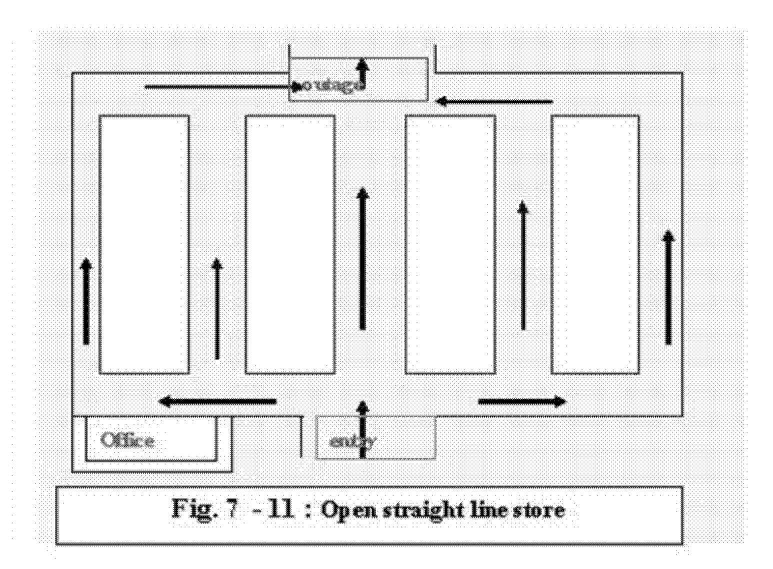


Fig. 7 - 11 : Open straight line store

3- Layout

Area of a store or a part of a store would be calculated on the basis of some knowledge although it may be considered for a long term condition. Then, initial parameters and information may be the way for study and calculating the area required.

a) Type and quantity of stored objects.
b) Time of storing.
c) Minimum quantity of storing for each.
d) Rate of use (store outage).
e) Area of storing inside.
f) Tools of storing process (lifts, cars, ...).

g) Tools of stored object (box, bottle, ...).

h) Auxiliary area required for the process of storing, dispatching or discharging and outage.

i) Rate of (in / outage) processes.

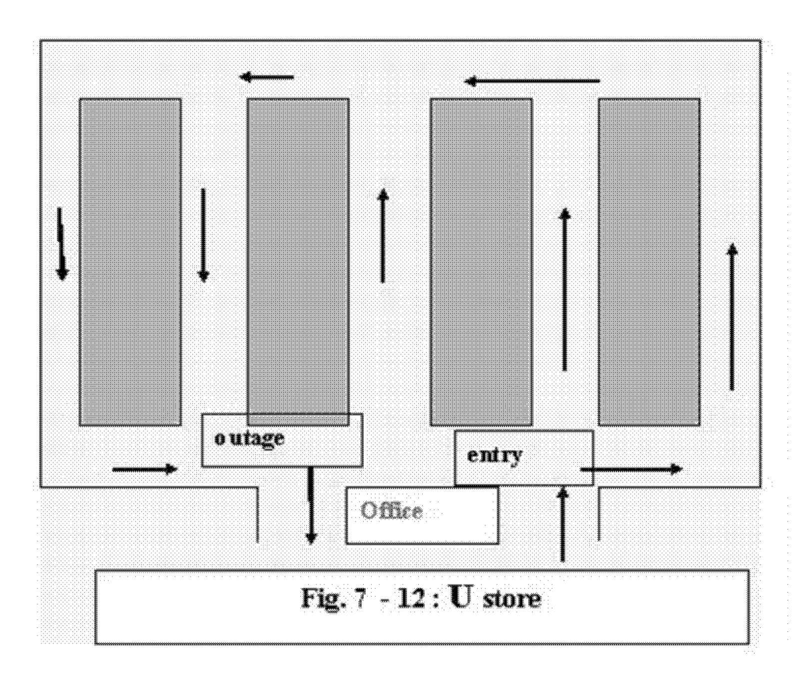


Fig. 7 - 12 : U store

I- The plan of a store

A store may be classified as: Outdoor store or Indoor store. This may be reclassified either single floor or multi according to all requirements and restriction for such design.

The most spread shapes of stores may be indicated in drawing as a plan as:

a) Open straight line store

This is one of the simplest forms of a store where it is suitable for heavy and over heavy objects such as big HV power transformers. This type of stores has been drawn in Fig, 7 - 11.

b) Closed store in letter (u)

In such location the movement, as indicated on the plan of Fig. 7 - 12, is done as the letter U although the entry and outage are at the same side. It is suitable for correct supervision for small and very small objects.

c) Circular (ring) store

This type is suitable for controlled condition of storing such as frozen objects and that similar. Its plan is given in Fig. 7 – 13 where the entry is located besides the outage point.

d) Spiral (screw) store

It is a multi S shape or it can be titled as Zigzag type where its plan is shown in Fig. 7 - 14. The rout would be designed so that unidirectional concept will be the way inside the store. Thus, it is needed to consider the next items.

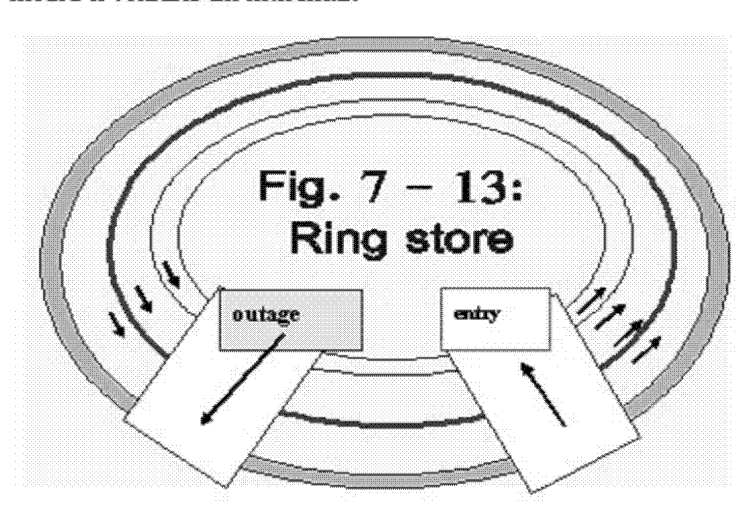


Fig. 7 – 13: Ring store

i- Maximum utilization of the area.
ii- Determination the best rout as well as the office of supervision.
iii- Suitable standard lighting.
iv- Good ventilation.
v- Allocation of offices at the way terminals.
vi- Design the lifting tools inside.
vii- Safety of labor
viii- Safety engineering rules and fire fighting as well as the emergency doors.
ix- Alarming and sensation complete system.

4- Tools

The most important of tools in stores may be abstracted as:

i- Loading units
ii- Transporting equipments
iii- Lifting tools
iv- Pulling ways
v- Transfer technique

This item may be classified in three categories such as:

a) Manual transfer
b) Automatic transfer

This transfer can be done with lifts and cranes where some restrictions may be necessary such as:

i- Reducing the transfer processes as possible.
ii- Avoidance of cascading process during transfer
iii- Minimize loading and discharging operations
iv- Automatic dependency in transfer cases in order to utilize the area and minimize the damage risk as well as effort.

c) Full automatic (Robotic) transfer

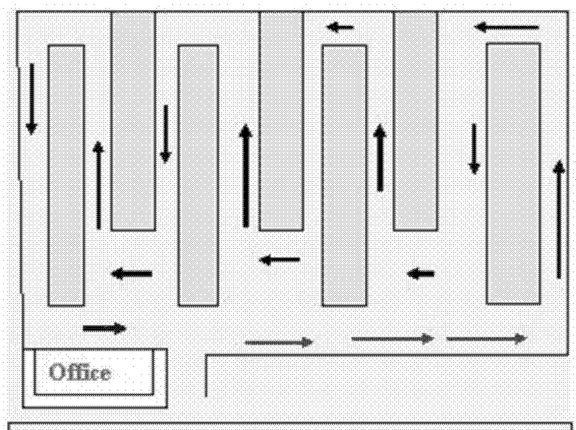


Fig. 7 – 14 : Screw shape store

Chapter VIII

SINGLE LINE DIAGRAM

The network is working according to the 3 phase performance where the circuit will be compressed when drawing. The single line diagram (SLD) is the solution for such a problem overcoming. Therefore, the (SLD) will be the base for a design process for a station in spite of its un-completely for all items in the circuit. It is still the best solution for the complex diagrams on sheets. Otherwise, the 3 wire diagram may be implemented but only where required. Then, the process of design a station begins at the (SLD) and consequentially the next discussion will be important for the subject under interesting.

8 – 1: BASIC RULES

There some rules must be determined before beginning such as:

1- The level of power

This means that the bulk power or small or medium. Also, whether the power utilized in site or far away or both.

2- The level of voltage

The voltage level is very important to decide the type of installation so that the simple or complex connections may be considered. This level plays a great role in the design process from the all items of design view. This will be explained later in more details.

3- The number of units

The number of units differs from the level of the power in that the units may be small for a small station or a small for a big station.

4- The area available

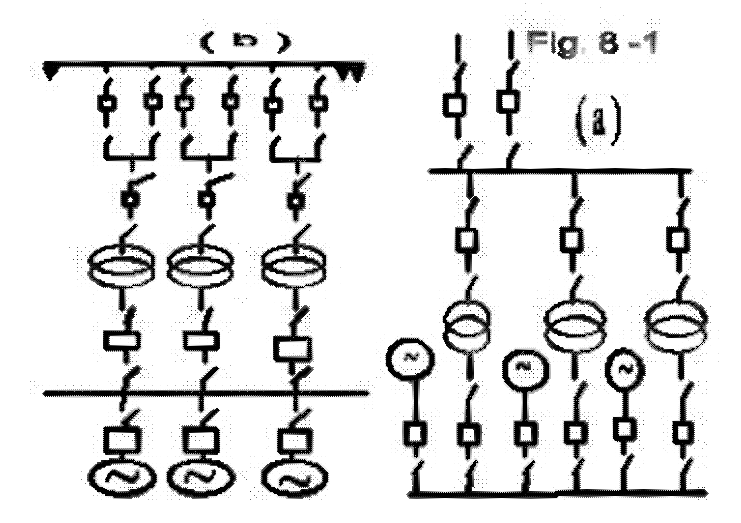
This area may be opened value if the station is built in the desert or a certain area not more inside a zone. The design may be moved towards a certain technology with different styles of items. Then, various possible can be proposed.

5- The type of station

Type of station can be classified as known as P. S. or S. S. or distribution or others as given in the last above chapter. It may be installed in an open area or inside and other type classifications as will be explained later.

6-Types of Circuit Breakers

There many different types of CB which are used in HV level so that the type of CB plays a great role in the shape of the station. The CB type is an important item although it has nothing in the single line diagram. That is the type of CB affect the design of the station while the *(SLD) is not depending on it. The types of CB may be SF_6, Oil, Air Blast, Vacuum or others.*



7- The directions of incoming and outgoing lines

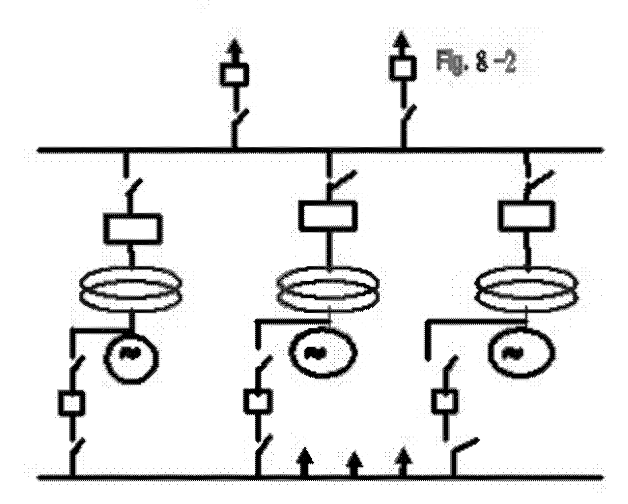
In order to allocate the direction of the station, the directions of outage connections would be defined. This means that the direction of the sides of the station under design depends on the directions of lines connected. The possible directions can be single, double, triple or multi as well as single level of voltage or more.

8- The possible allowable tolerance

Sometimes, the design will be controlled according to some restrictions. These restrictions will affect the design so that they should be known at first before the design process. Such controllers could influent the shape of the station or the connection or the level of voltage or even the type.

9- Type of auxiliaries required

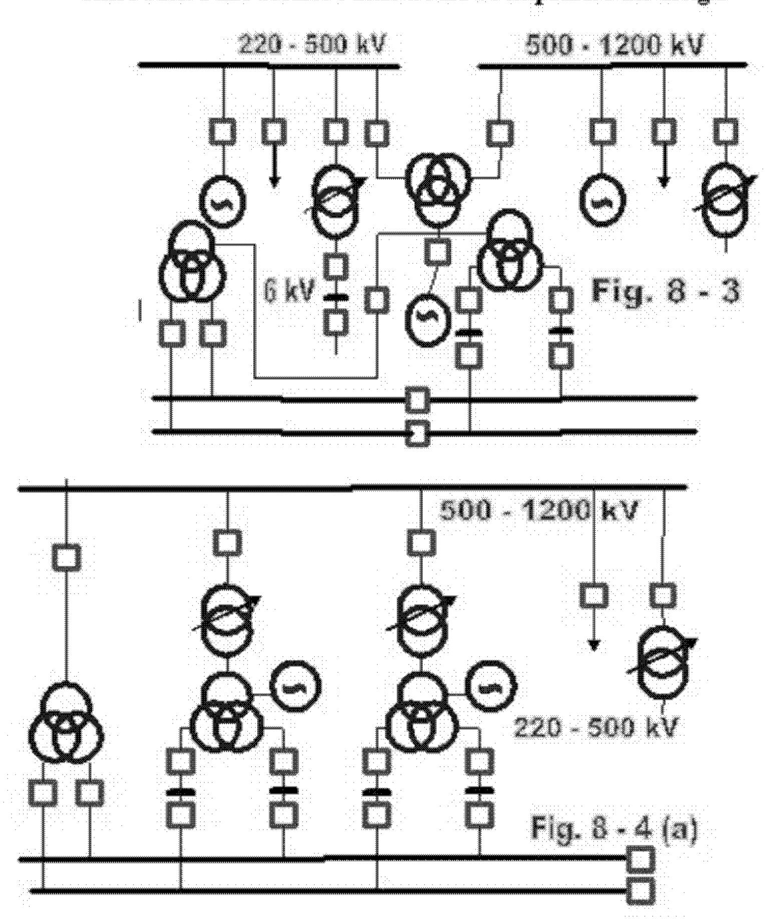
Auxiliaries include a lot of components that takes a role in the (SLD) when design so that their presence in the station would be considered from the *begging*. The fire fighting or pumping of water or earthing type may be subjects for the item proposed. This subject will be introduced with explanation next.


Fig. 8 -2

10- Performance of the measuring transformers

The presence of the measuring instruments in a station is essential and their type is important. This related to the protective schemes and circuit used. The relaying style will be a point to lead the design in a certain direction.

These basic rules besides others would be helpful for the design.

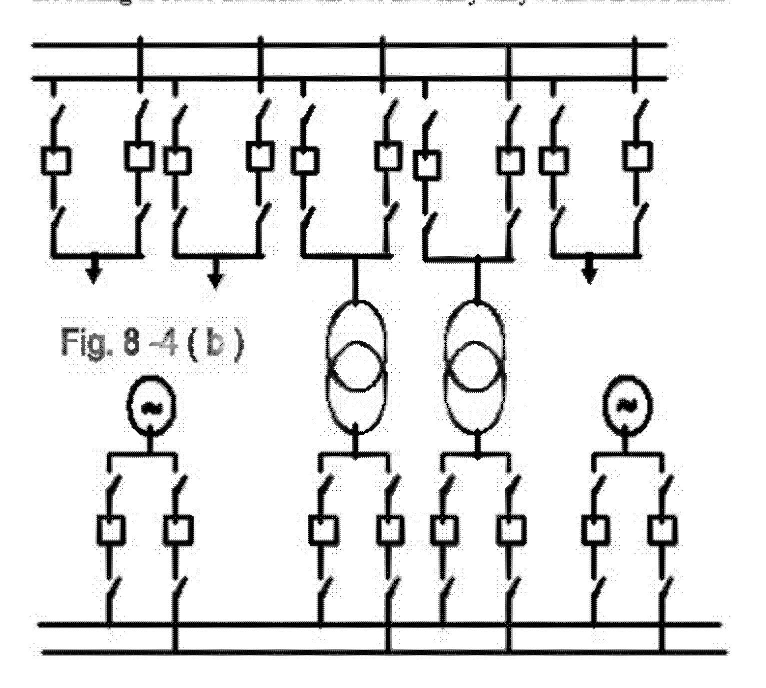


8 – 2: Stations

Electric stations can be classified as written below and the different connection for each may be presented.

1- Power Stations

It is the station in a network because it is the supply which bring power to the consumers. Their connections depend on the BB style according to some different factors and they may be illustrated next.



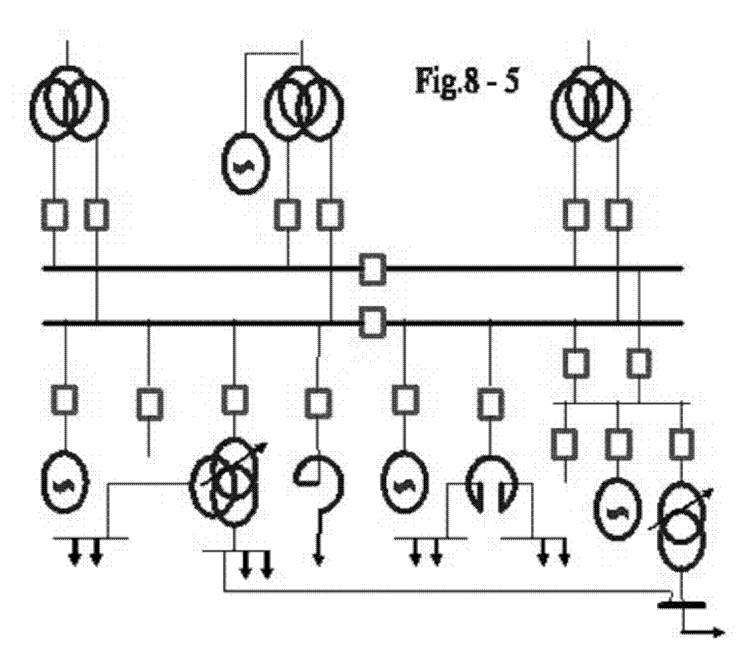
a) Single BB single low voltage level output

Single BB at a low voltage generation may represent the simplest form of connection to a power system where it is known as the generator unit. This is a traditional type of generation that spread all over the world.

This sample of connection may be drawn in Fig. 8 – 1. In this case a standby CB may be installed in the circuit as given in circuit (b).

b) Double generation level BB

The use of double generation voltage level is built on the idea of reliability for the various connections with a generator. This means that a station may be connected to a power systems in more point while the proposed concept will raise the reliability factor. It may be in different shapes of connections as shown in either a (where low flexibility) but it can be installed for hydro P. S. or b scheme. Fig. 8 – 2 presents such a diagram to illustrate the proposed technology.


Fig.8 - 5

c) Multi level connection

Whatever with increasing the level of connections between a power station and a power system, the reliability performance of operation for such systems may be high. A multi level connection diagram has been drawn in Fig. 8 – 3. It may be also as HV levels / LV sectionalized BB which means that each section for each main side (Fig. 8 - 4), a or double voltage double BB with single or double CB style as in circuit b. On the other hand, for typical types of Power Stations we introduce some of these Power Stations as follows:

I- Thermal Power Stations

Thermal Power Stations are the oldest type of power stations in general that used in all countries of the world. It is the most used type and the connections for typical stations would be presented as:

a) Basic Scheme

Since the thermal power stations have been constructed a long time ago, its standard has been evaluated. This leads to the meaning that the single line diagram for such station must be standardized and consequently a basic single line diagram may be initiated as shown in Fig. 8 – 5.

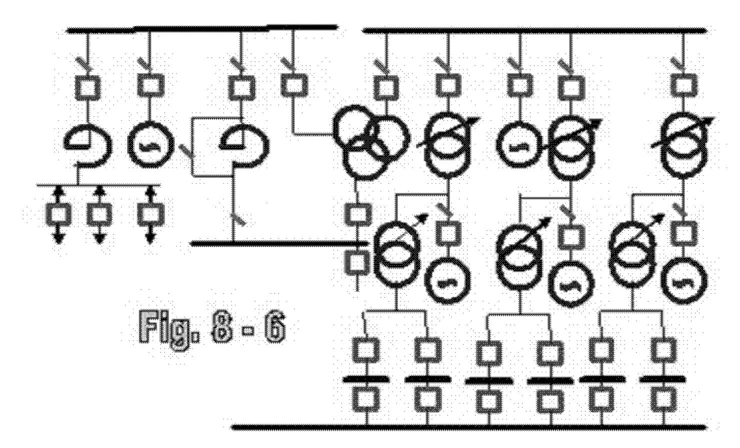


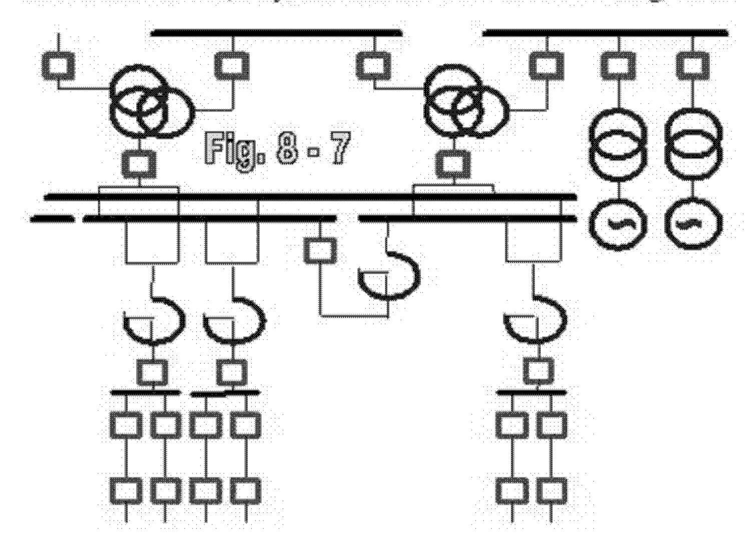
Fig. 8 - 6

b) Line Reactor Scheme

A reactor is necessary to be utilized in a single line diagram for many reasons however it is very important for the transmission line operation as shown in Fig. 8 – 6. It is seen from the figure that the reactor can be used as a short circuit limiter in two shapes. The first style may be that which uses the reactor in series with the line in two forms. They are the continuous connection in the circuit or the automatic connection during a fault occurrence. The second will be the parallel connection for compensation.

c) Large number of units / minimum sections

The insertion of a reactor in a scheme requires a mathematical analysis for the short circuit conditions if it will be a short circuit limiter. Also, the use of a reactor may depend on the number of unites connected so that for a large number of units a single reactor (as short circuit limiter) may be utilized. This case is shown in Fig, 8 – 7.



d) Large 0.4 kV 3 units Power Stations

Nowadays, the standard typical blocks of a power station may be specified as a typical station and then, Fig. 8 – 8 shows the single line diagram of a station with a large number of generating units at a very low voltage level. This scheme may be suitable for the local generation for a specified load in the place where the loss will be low due to the non-transmission phenomenon. On the other hand, these units can be easily connected to a power system as shown in Fig. 8 – 8.

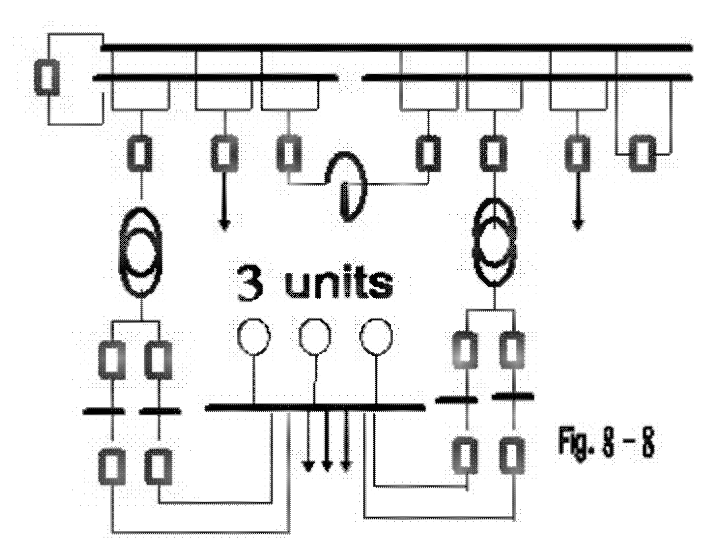
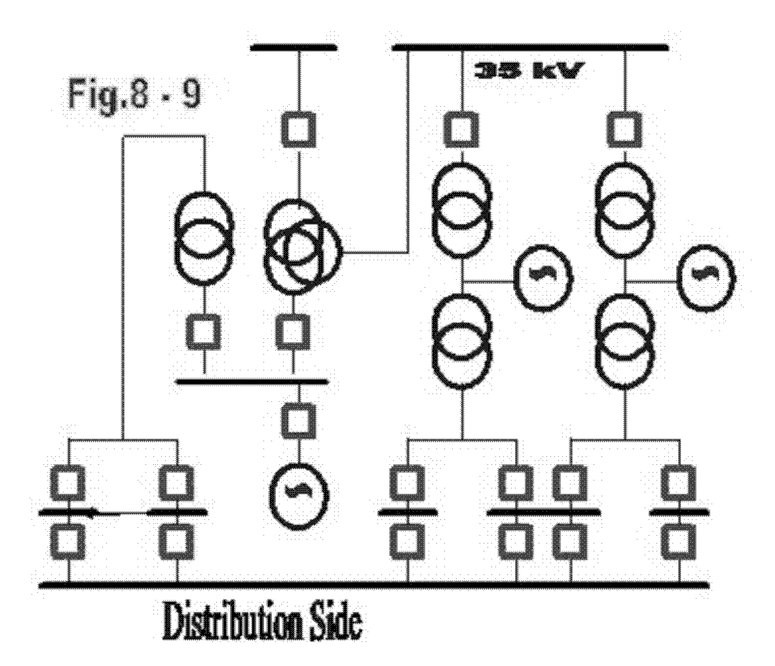


Fig. 8 – 8

e) Multi units station 6 kV

The industrial normal level can be considered in most cases as 6 kV in spite of other levels to be used. As typical example for the single line diagram a scheme for the 6 kV station has been drawn in Fig. 8 – 9. It must be noted that as the voltage level is approaching the consumer level, the connection to a distribution network should implemented. In the same time, a connection to the transmission network also should be considered.

This type of stations can be repeated in a group style in order to get more power. The multi units as a single group is a suitable style too for the hydro power stations as well as for diesel type.



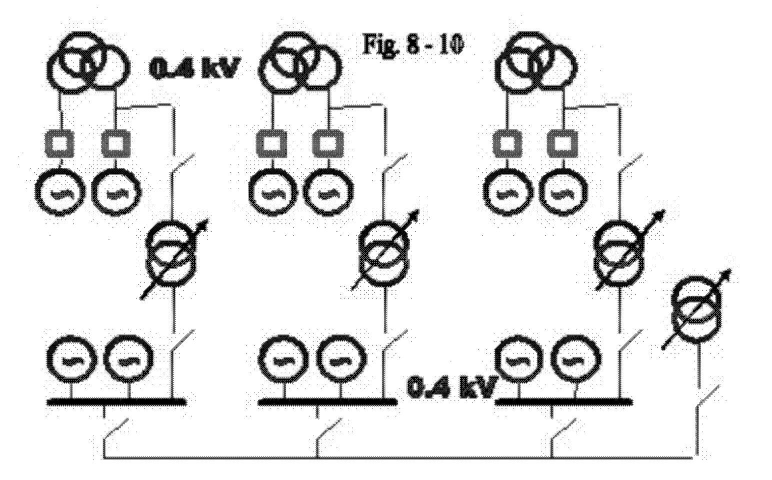
II - Hydro Power Stations

Similarly, there are some typical connections that may be tailored shortly as:

a) A Basic Scheme

There are many typical schemes for the hydro power stations where one basic single line diagram has been presented in Fig. 8 – 10. It shows that a grouping style is a basic either with solidly connected units or that separately connected units as shown in Fig. 8 – 10.

Since the turbine in a hydro power station may be small in size, a grouping concept will be more economic from the engineering point of view. This means that a grouping for a collection of turbines may be better because the turbines are depending on the civil construction of the dam. This grouping for the sum of generated power from the turbines leads to raise the level of power in the electric circuit. This may be seen in Fig. 8 – 10 when the triple windings transformers are used. It is seen that the turbine can supplies the output to a single winding of the triple winding transformer.



b) General Loading

This general loading may cause a weak connection for flexibility, reliability and parallel operation of transformers. It is characterized as all loads are at the same level so that a discrimination of loading type may be disappeared. This has been illustrated in Fig. 8 – 11. Such schemes may be applied for a certain zone where renewal population may be the target. Then, it is applicable but with a restriction for loading in most cases.

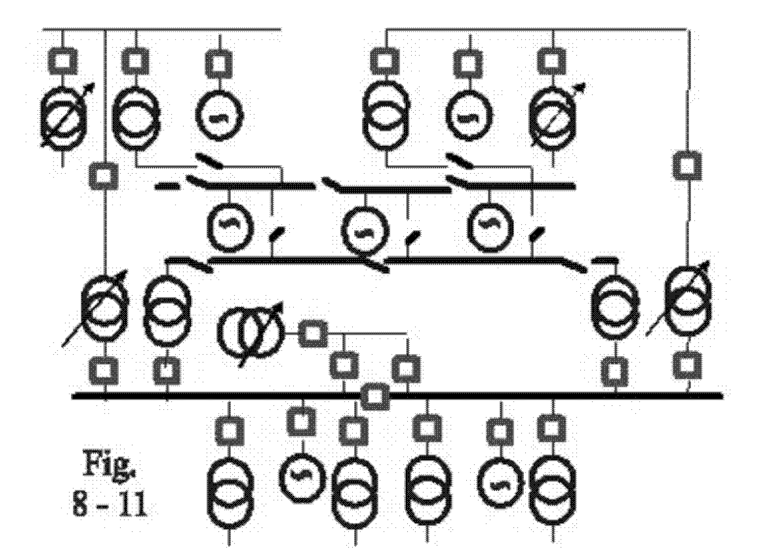


Fig. 8 - 11

c) A 0.4 / 11 kV low Power Generating Station

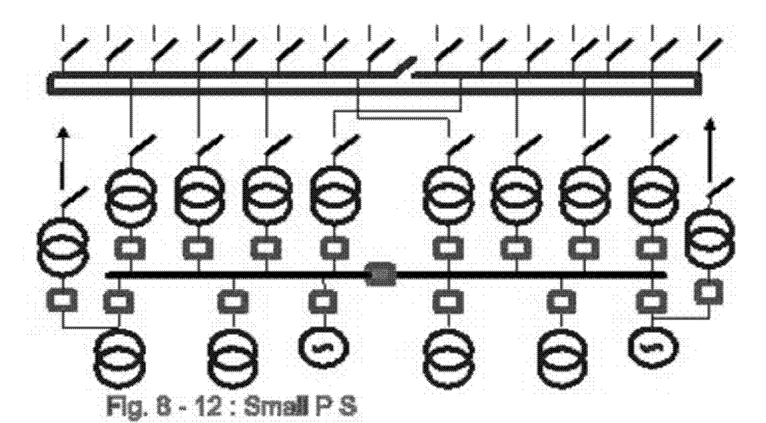
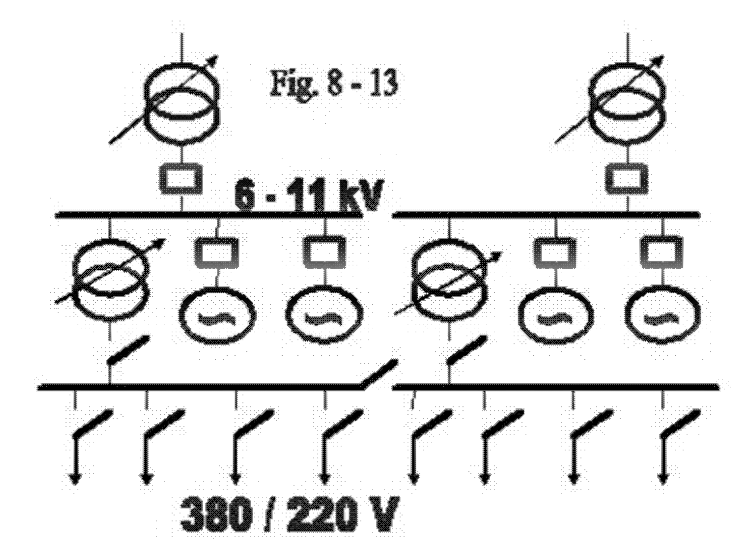


Fig. 8 - 12 : Small P S

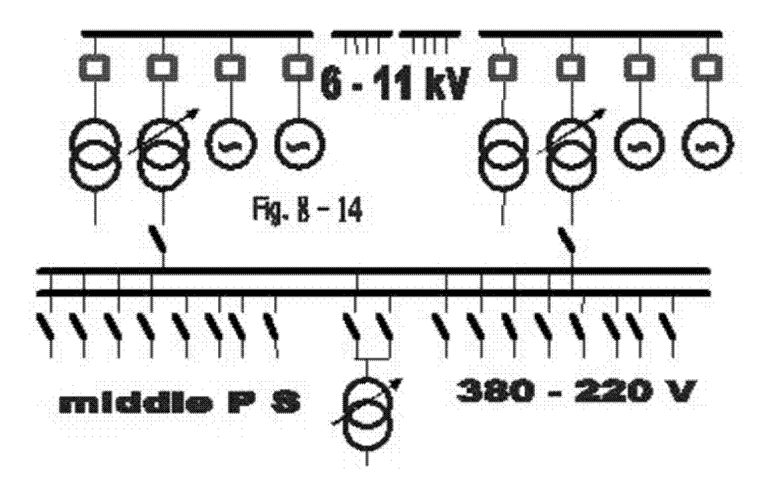
Sometimes, the small power stations may be very necessary due to the characteristics of loading in a place. It may be a small city or country loading in spite of some villages may consume a high power. This style of stations may be standardized as shown in Fig. 8 – 12 a lot of distribution transformers are applied in the scheme. The single line diagram is a typical scheme for 04 / 11 kV levels.
However, the hydro power stations in a network can be reclassified according to the amount of power demand in the three forms as given below:

a) Small Power Stations



Small power stations are normally spread around the world (Fig. 8 - 13) because this type of stations (Hydro power stations) depends on the water height difference. This may be the reason that the height difference of water on rivers almost mal so that a lot of stations can be constructed instead of a single big station.

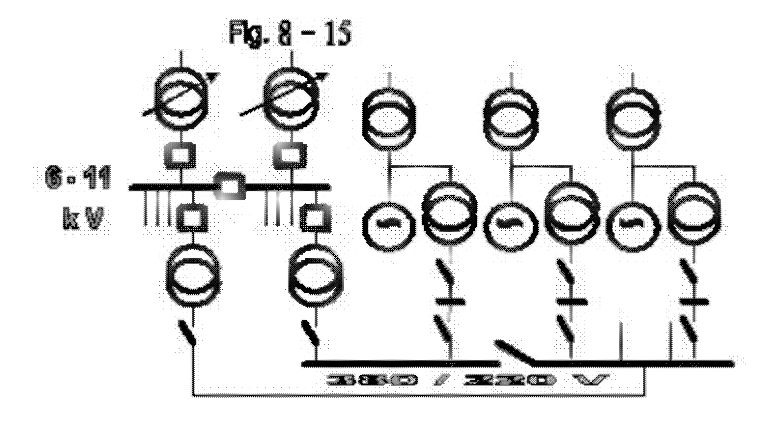
b) Normal Power Stations



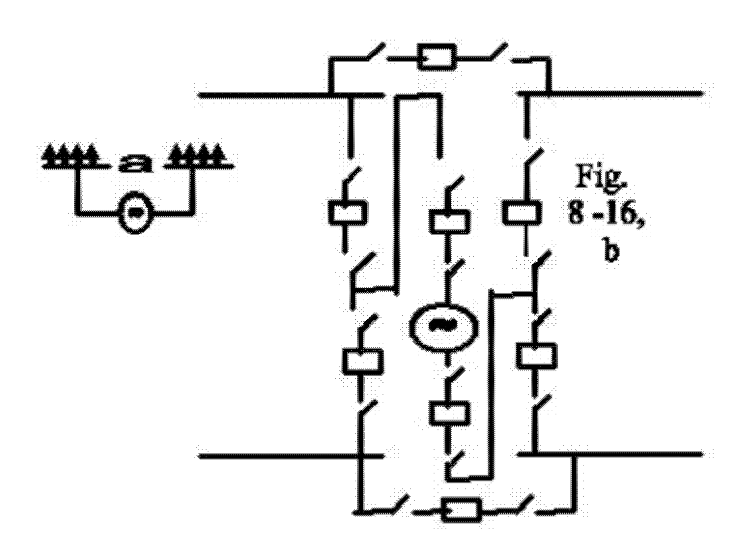
It should be mentioned that the small power stations are more expensive due to the civil works cost and then, a more practical way is the raising of the power level. Also, the said sentence means too that the big power stations are the most economic types of hydro power stations. Thus, the medium level of powers will be economic and better when the big dams are a difficult solution. Therefore, a single line diagram for a typical normal power station is given in Fig. 8 -14.

c) Large Power Stations

On the other hand. The best and optimal solution for the hydro power stations appears to be the generation of bulk power while it needs a high head difference on turbines. It depends on the nature of rivers as well as the other geographic factors so that it may be sometimes apolitical decision. A typical single line diagram for a large power station may be drawn in Fig. 8 – 15 where a multi flow direction can be used. The utilization of some of the generated power may be useful for the local loads.



III- Double winging generators



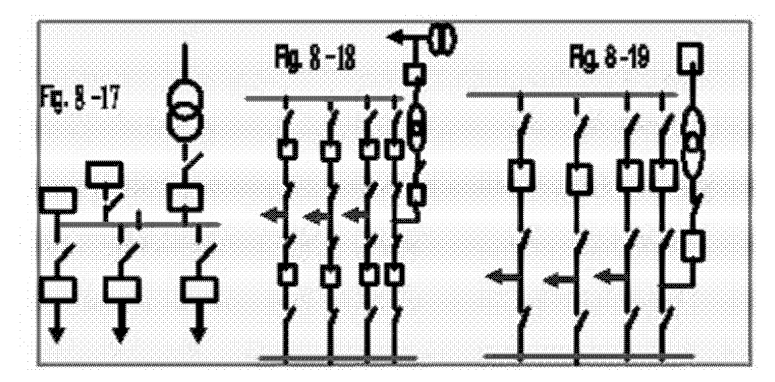
As the power level is raised, the generation may be too increased. This may be reached through the double winding generators where the power can be doubled. This may be used for any type of station and they mainly divided according to the connection to the BB as a single BB (Fig. 8 -16, a) or a double BB system as shown in Fig. 8 -16, b. It is seen from Fig. 8 – 16, (a) that a single generator having double windings where one gives a power for some loads. Thus, the second winding supplies the loads at its terminals.

2- Substations

The transformer stations are known as substations (S. S.) and they may classified as given before according to the purpose setup or down or others. Now, the connection type will be divided into two main poles:

I- Traditional Pole

Traditional pole may be standard as its typical classification may be explained below. This includes some types of connections such as:



a) Single supply single BB

The simplest system in this classification may be the single supply single bus bar as shown in Fig. 8 – 17 where a CB is used besides a disconnecting link per each load.

This means that a small power consumption in each so that it may be recommended for the terminal user applications. It is also, suitable for the service loads inside a station.

b) *Single BB double supply system*

It is a more reliable if we increase the supply sides as the given here the single bus bar double supply system. The single line diagram for such case is given in Fig. 8 -18 where the scheme explains the two independent side supplies for feeding loads on the basis of single BB system.

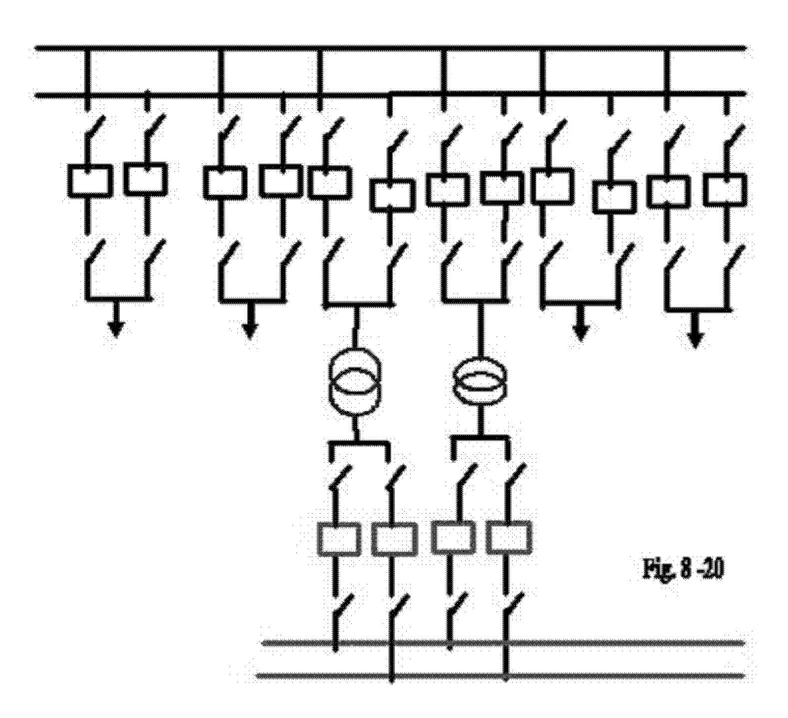


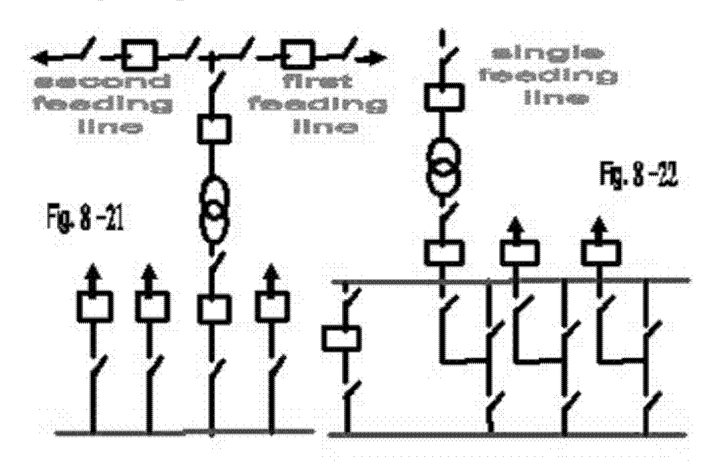
Fig. 8 -20

c) General use BC double BB

Generally, the double BB can be implemented in order to raise the level of connections as explained before in the present book. Fig. 8 -19 presents the single line diagram for such case while the scheme illustrates the double BB with the help of bus coupler. Then, feeding the terminal loads on the basis of a double BB system may be better than the single BB systems.

d) Double CB double BB

However, the most practical standard for the single line diagram appears to be the double BB system (Fig. 8 -20) with the use of double circuit breakers in spite of its expensive cost. Then, this scheme may be important for the level of voltages as EHV as well as UHV so that the benefits for the reliable use of circuit breakers may cover technically the expensive cost.



II - Improved Pole

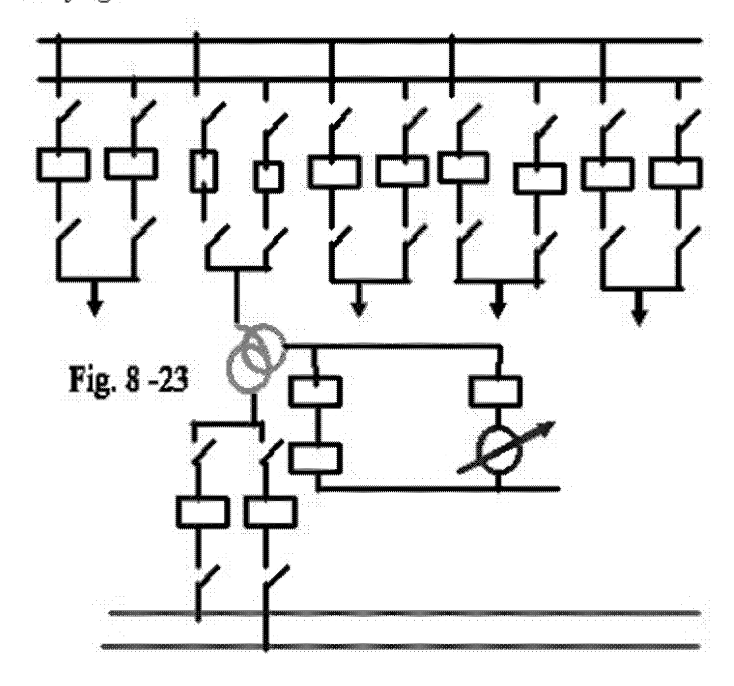
The second style of poles appears to be the improved pole where the new improved connections can be presented here and tailored in the next forms:

a) Double feed line single BB

The feeding concept means the input power direction to the specified station and then, a single line diagram for a substation has been drawn in Fig. 8 -21. The station output may be single or multiple out going transmission lines.

b) Single feed line double BB

Contrary, a single transmission line may supply the substation as shown in Fig. 8 -22 while a double BB system has been given in the drawing to indicate that the power rating for such stations would be large. This style may be needed for stations at HV or higher levels of voltages where the transmission feeding line is a heavy current carrying.



c) A multi feed line with auto-transformer

Auto-transformers are widely used in electric power networks although its capacity was seen as a low power performance. It is now installed as a main transformer in heavy power substations as shown in Fig. 8 -23 where the transformer is triple voltage terminals.

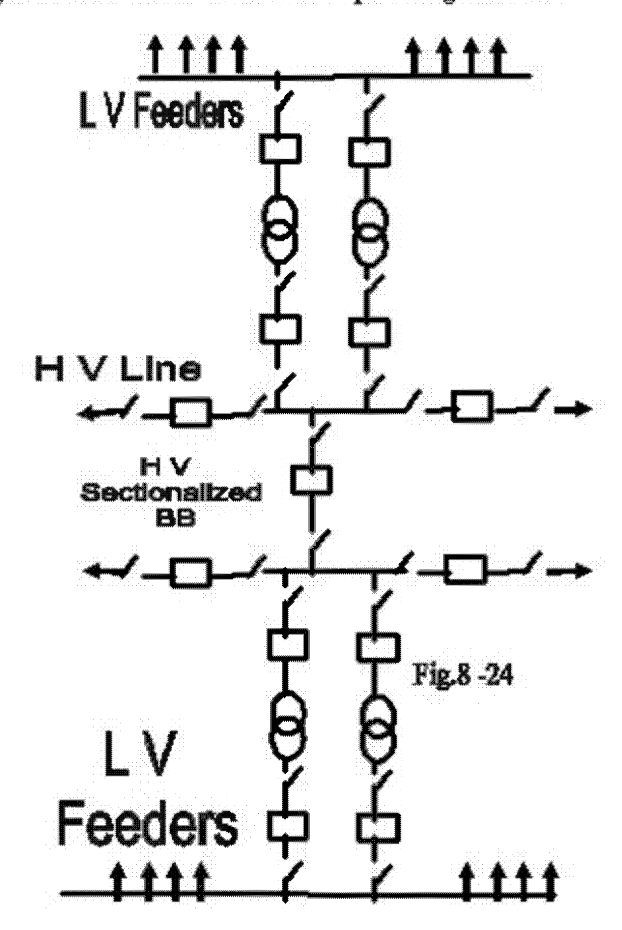


Fig.8 -24

The lowest voltage windings has been considered for the control circuit. It should be illustrated that the outgoing transmission lines are a lot of lines while the input feeding lines are similar. This represents the large power substations specially that with EHV or UHV levels of voltages.

III- Advanced Pole (Sectionalized HV BB)

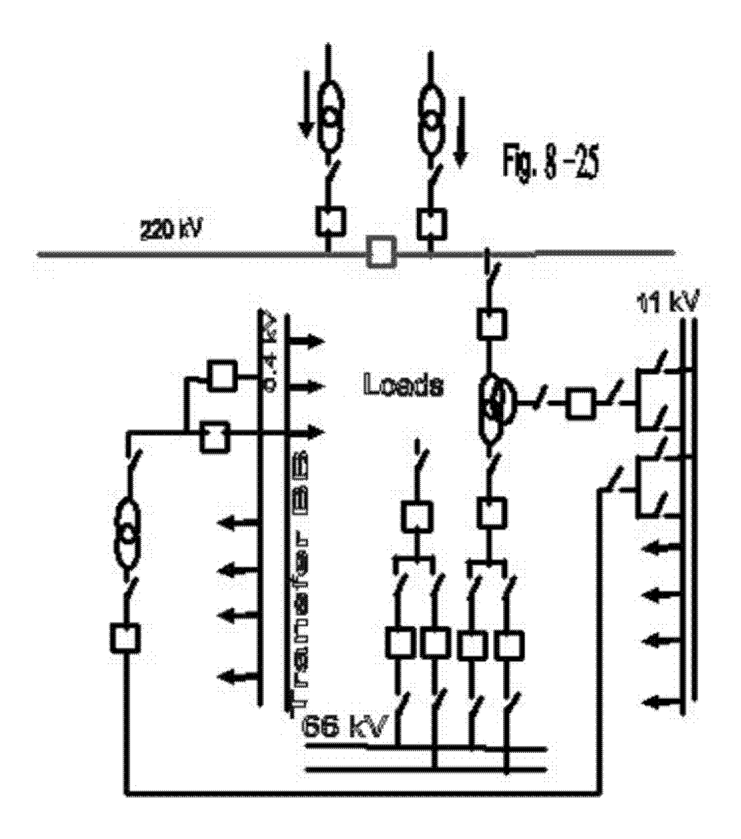
The third class will be the most advanced type where it is known as advanced pole (Fig. 8 – 24). It means in another view the sectionalized BB system in a HV station. Sectionalization would be a concept for the station connections while the BB must be partitioned into two or more parts. Each part is called as a section. This advanced pole is the most suitable one for bulk power S. S. while the connection diagram has been drawn in Fig. 8 -24 .

3- Distribution Station

The distribution stations vary in shape according to the number of transformers inside such as Single, Double, Triple or Multi Transformer Distribution Station. Each of these will be defined according to the voltage level as:

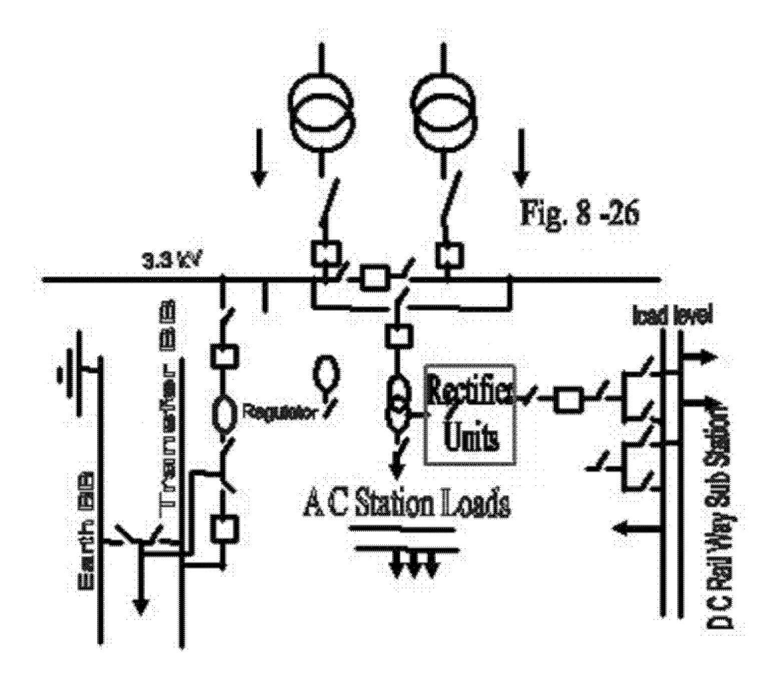
1- Single voltage outage

This case appears to be the scheme of feeding a power to a small or normal or even large power either at consumer at the distribution or utilization voltage or at the terminal points in the transmission system. It is a simple form of the other complicated schemes for stations. Then, it is the used style for feeding an apartment or a small workshop or a micro supermarket at a single specified voltage or for connection between stations. In all cases only one voltage output for the station where a power station scheme will be like this if it has no other voltages output. It means that a substation will have a single output voltage besides a single input voltage although this is not required due to the interconnections and their benefits.



2- Multi voltage outage

The general free connection in a station represents a wide range of applications with respect to the restriction for the voltage output. This concept is given in Fig. 8 – 25 where three level outage is drawn. They are 11 , 66 and 220 kV outage for a substation. This means that the connection to a network can be implemented at any of them. Also, it can supply directly a load at one of the outage voltages.



3- Converting Stations

This station may be simple if it is a rectifier station. Otherwise, the rectifier station can transform the AC currents into DC currents while the converting station will be more complicated. The DC generation station is a shape of rectifier stations is drawn in Fig. 8 -26. In electric stations a DC station is important inside it but a special individual DC station may be needed if the load is working on DC. Also, the DC stations may be required in some laboratories. The present station in this title is the converting station where it transforms the DC supply into a AC output.

4- Railway Stations

DC stations are the specified type for the supply of the railways and consequently a single line diagram for a rectifier station is given in Fig. 8 -26.

5- Double BB Schemes

A typical single line diagram on the basis of double bus bar system may be given in Fig. 8 -27 where both main BB and auxiliary BB are illustrated on the scheme.

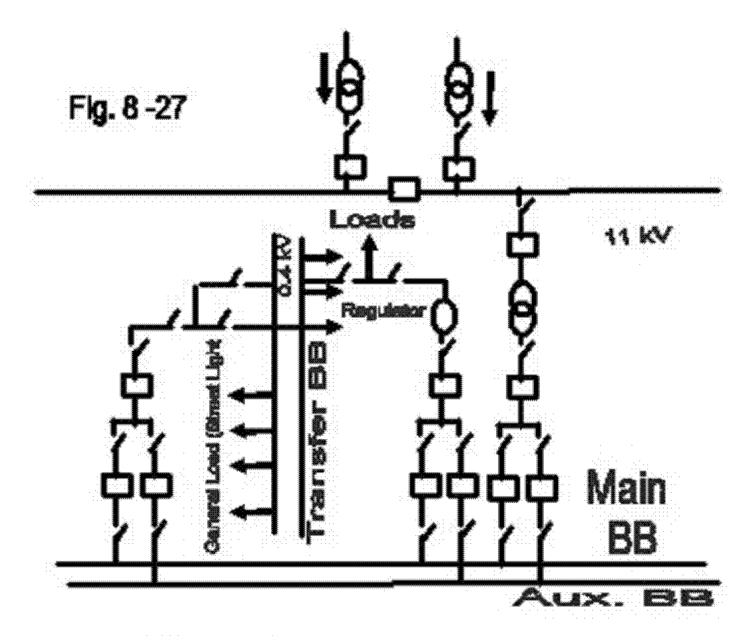


Fig. 8 -27

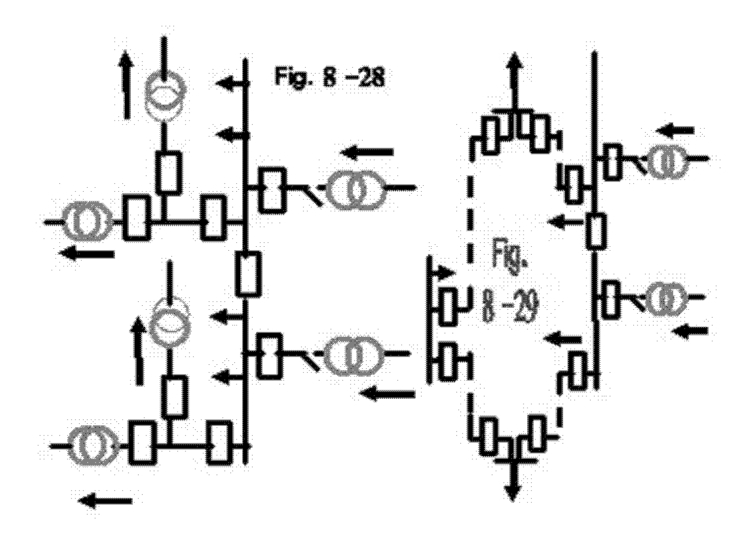
6- Switch Stations

Finally the switch Stations may be classified as a CB arrangement station for the purpose of flexibility of different connections between either stations or lines in a network. This may be required for the connection between united networks and sometimes inside a single united network between different parts.

On the other hand, all of these above stations could be rearranged with respect to the SLD inside a power system as a whole. Therefore, the electric power supply as a united network in the distribution level may be classified in the form:

i- Radial Outage Scheme

This radial scheme will supply the loads directly as it is given in Fig. 8 -28 in a simple shape. It is convenient for the distribution system which means that is a main SLD for terminal consumer stations. Each distribution station will supply a part of loads in the flow direction shown in Fig. 8 –28.



ii- Ring Feeder System

The ring feeder as shown in Fig. 8 -29 represents a more reliable scheme, and consequently a power system, in operation while it may be based for the station in connection with the system as a whole.

It is used for the power system as the BB systems inside a station so that a ring configuration may be more reliable than that of radial style. It may be reliable for the higher voltage step in the distribution system. Double supply may be controlled automatically to cover any interruption in the operation.

iii - Multi Feeder Distribution

The single line diagram of a distribution network including various substations may depend on a multi feeder style as shown in Fig. 8 -30 that the arrangement of power flow may be distributed as indicated on the scheme. It is the case of distribution of power in a distribution network.

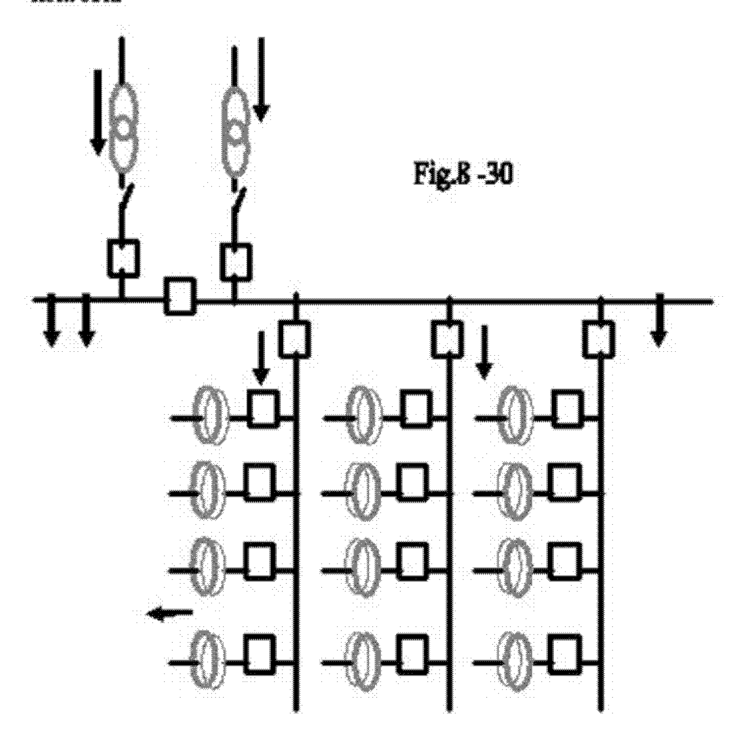
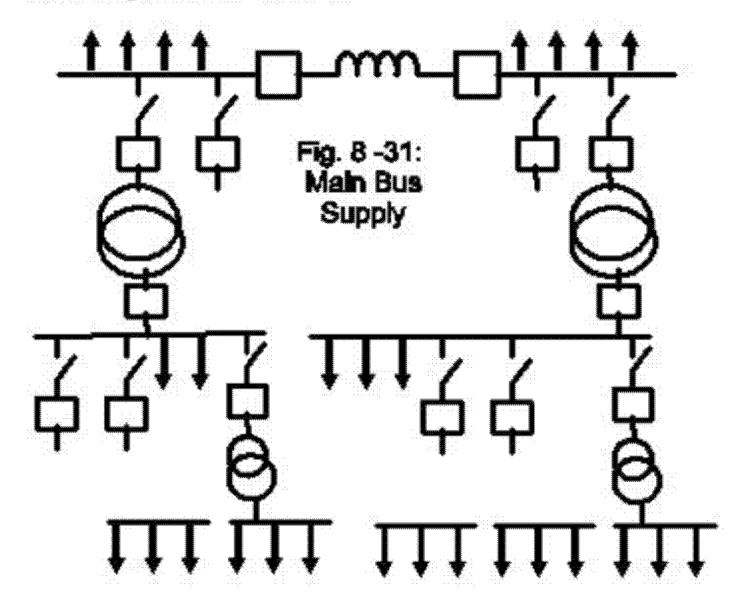


Fig.8 -30

8 - 3: AUXILIARIES

Auxiliaries in an electric station depend on the type of Loads needed inside. For example, a power station needs some internal loads such as: (water / Fuel pumping – Cooling fans & pumps – Air Compressors – Fire Fitting – Lights – Rectifiers – Control – Measurement & Recording – Heaters - Others).



Supply facility type appears also, as a basic factor in the determination of such auxiliaries such as: (Main BB – House Transformer – House Generator – Shaft Generator – Motor Generator Set – Outage of the distribution network).
On the other side the types of loads may be indicated in classes as High importance (class A) or Normal load (class B) and the non-important loads (class C). Similarly, characteristics of the supply take a role in the process where it is A C or D C where usually both are presented and required.

Therefore, the scheme configurations can be played a role as given in items below.

1. Small Power Stations

This item may be considered for many connections although it may depend on the type and place of the station. Connections or single line diagram can vary the characteristic of loads (class of importance) but here the fundamental scheme for small stations mainly will be introduced as:

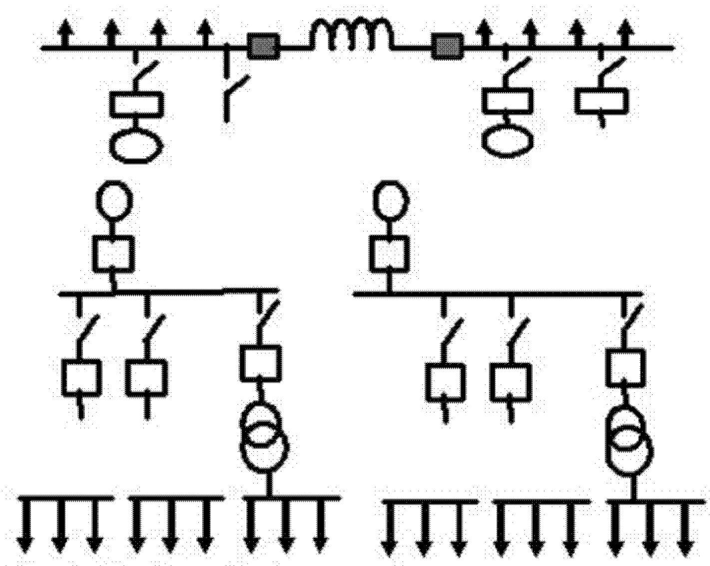
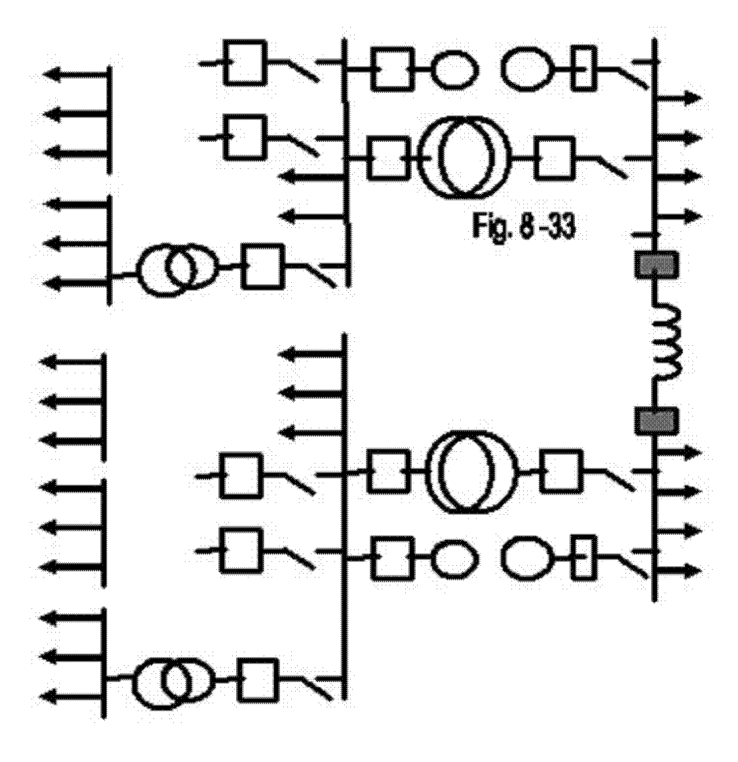


Fig. 8 -32: House Turbo-generator

1- Main bus supply

However, one of the major item in the connection of a station appears to be the main bus bar as drawn in Fig. 8 -31 where a reactor sectionalizer has been used. It is important for the reduction of the short circuit level at the bus bar.



2- House turbo- generator supply

Otherwise, a house turbo – generator is applied as a supply while its single line diagram is shown in Fig. 8 -32. It is a radial concept for the load flow although the grouping style has been considered. Also, the connection of a generator may be mainly supply a certain part of the connected load.

II. Large Stations

When the power is increased the connection diagram becomes more complicated for importance of supply. This may depend on the control requirement as well as the security and reliability of operation. A power station in these cases needs the big heavy power transformers so that it may be the outage face for it. Then the classification of schemes for heavy power electric station would be:

1- Double supply Type

Similarly, large power needs a special control and more restrictions for operation and maintenance although the present tendency is directed towards the a big alternator unit. However mainly there are a distributed concept for the load on the generators on a station where a sample for the single diagram foe such cases has been driven in Fig. 8 -33.

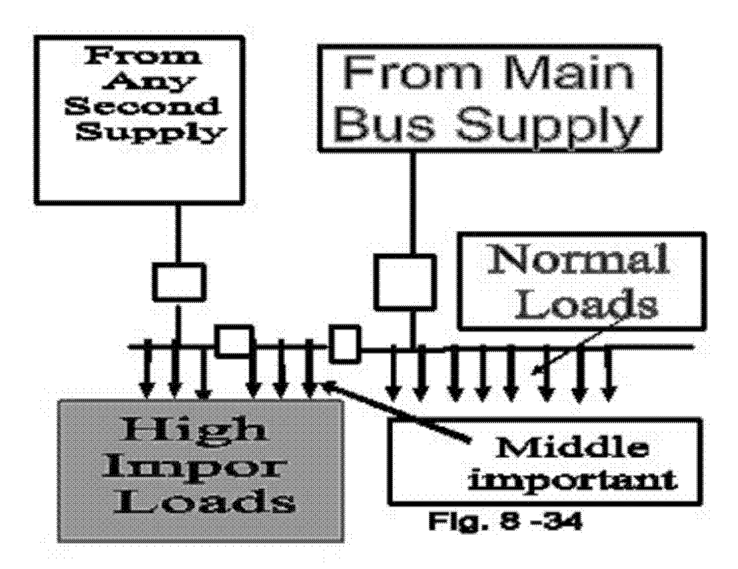


Fig. 8 -34

Otherwise, a double level for the connection of generators in the station has been indicated while the station is halved between both generators of the double level of connection.

2- Load class principle

However, the level degree of importance of a load supplied must be known before the distribution of loads on a generator. This may be appeared on the single line diagram where one of SLD is given in Fig. 8 -34. It is shown that the importance of a load is directly depending on its place on the BB where a major principle puts the first class of importance in the middle part of a BB. It means that the possibility of supply from two generators. Also, in a network this principle can be transferred to be between two stations (as each station as a generator).

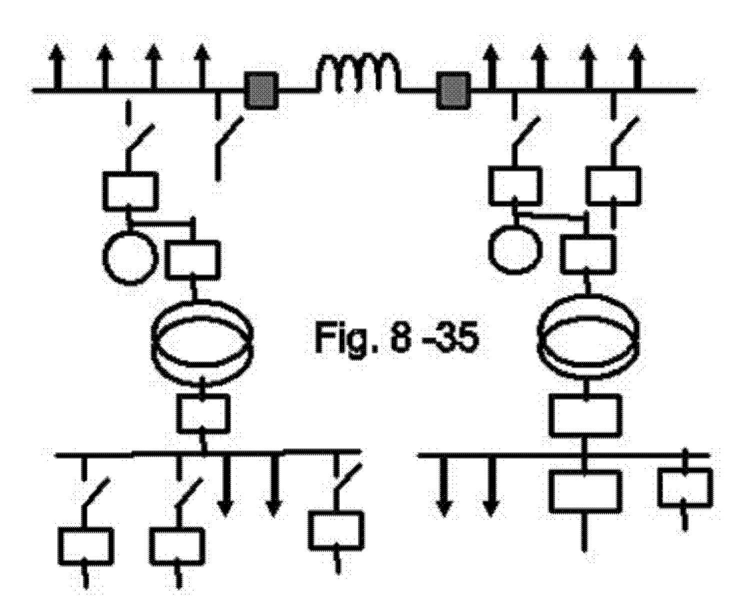
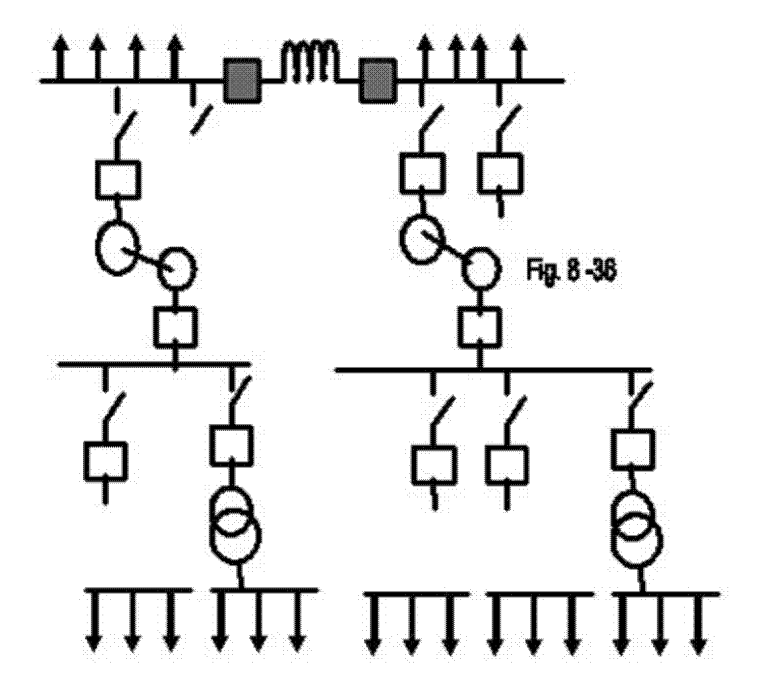


Fig. 8 -35



3- House transformer at generator leads

Whatever, the load is usually connected to a transformer so that a house transformer at generator leads may be appeared in the SLD of Fig. 8 -35.

4- Shaft generator supply

A special attention to the control of generator speed in a power system is considered because the operation of a power network can not be stable for different speeds of generators. This is the synchronous speed of alternators. So that it may be controlled a the mechanical balance transfer.

This is a stability speed for the alternator in general and then such schemes for the control of the shaft may be illustrated in Fig. 8 -36. It is a great item in auxiliaries of a station.

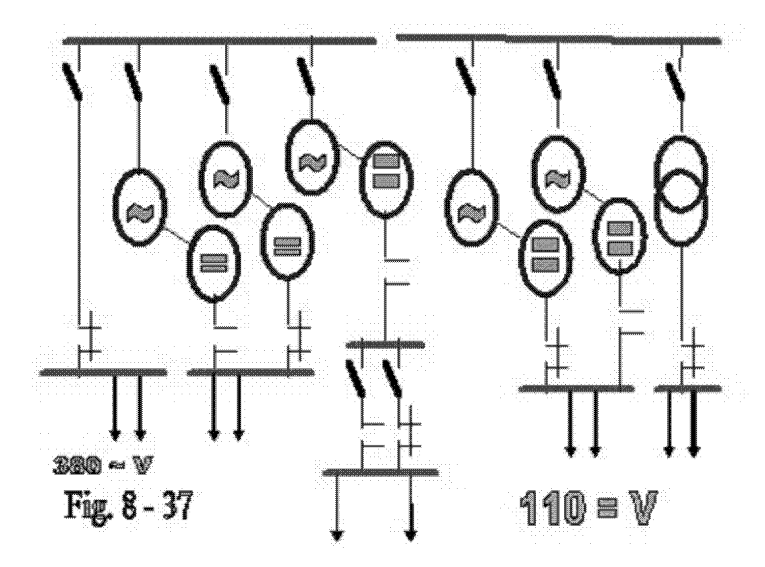


Fig. 8 - 37

III - Typical Circuits

Since the construction of electric station becomes a commercial product so that a standardization concept would be given. This step may help well in economic view of a country because it will be easy to maintain and replace any element or part in the station. There are many known typical circuits for the connections of auxiliaries such as:

1 - Motor generator unit

As a DC station would be installed inside an electric station for the purpose of supplying the protective devices and circuits inside, different systems for the DC generation may be considered.

The, a motor generator can be one of theses concepts (Fig. 8 -37). It will be AC motor / DC generator unit where the AC supply should be the supply of the station itself. There are many other concepts such as rectifier unit. Also, a charging method may be added in this attention in order to check a continuous situation of the battery station.

2- Main pumping for water station

Another type of auxiliaries in a station appears to be the water pumping because the water in normally used in EHV and UHV station for the cooling media of transformers (Fig. 8 -38).

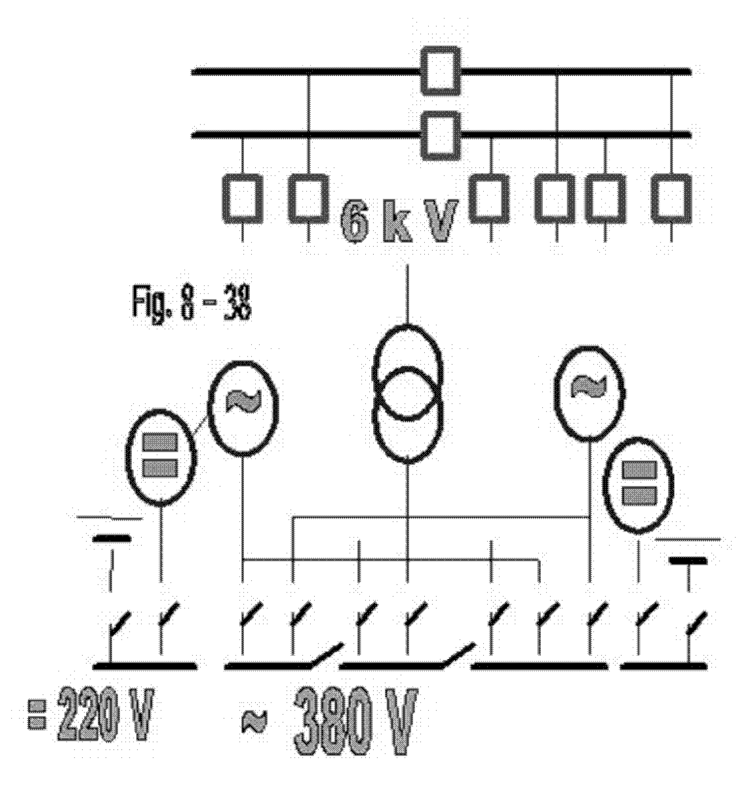
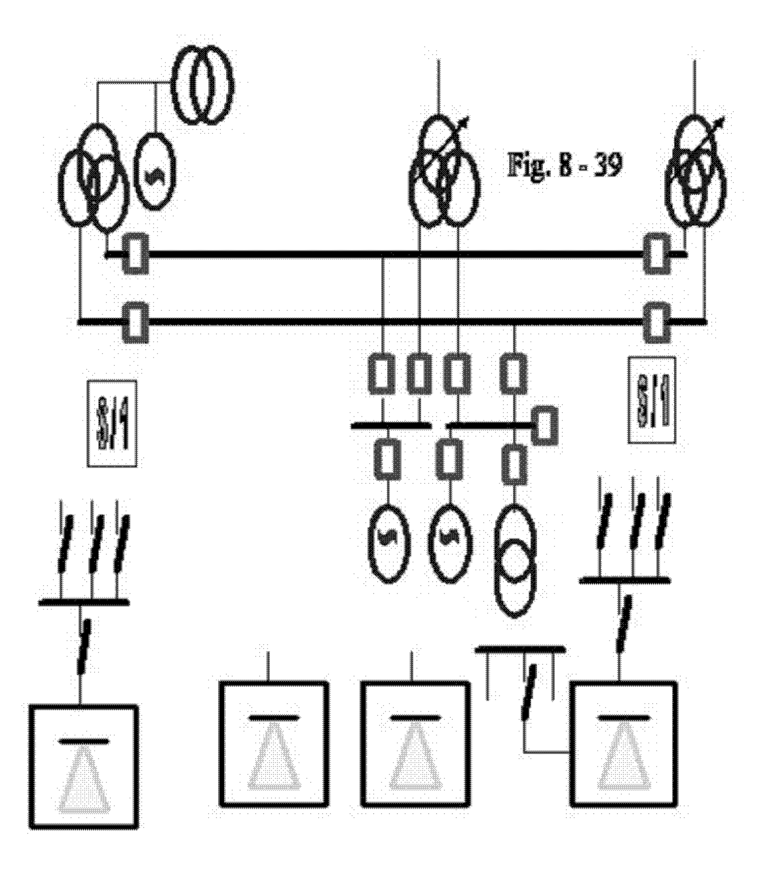


Fig. 8 – 38

The distilled water may be used too in electric stations but the major factor for this item is the pumping load and its schemes in the stations. This pumping may be for fuel in power stations or water as said above or even oil.



3- Pump station with protection

A pump station may be required for big station to supply the station with the pumped media. This station may be for air compression in order to supply the CB in the lay out of a station by the necessary amount of air under request.

This station may work according to a standard SLD as shown in Fig. 8 -39. A protective circuit can support such stations.

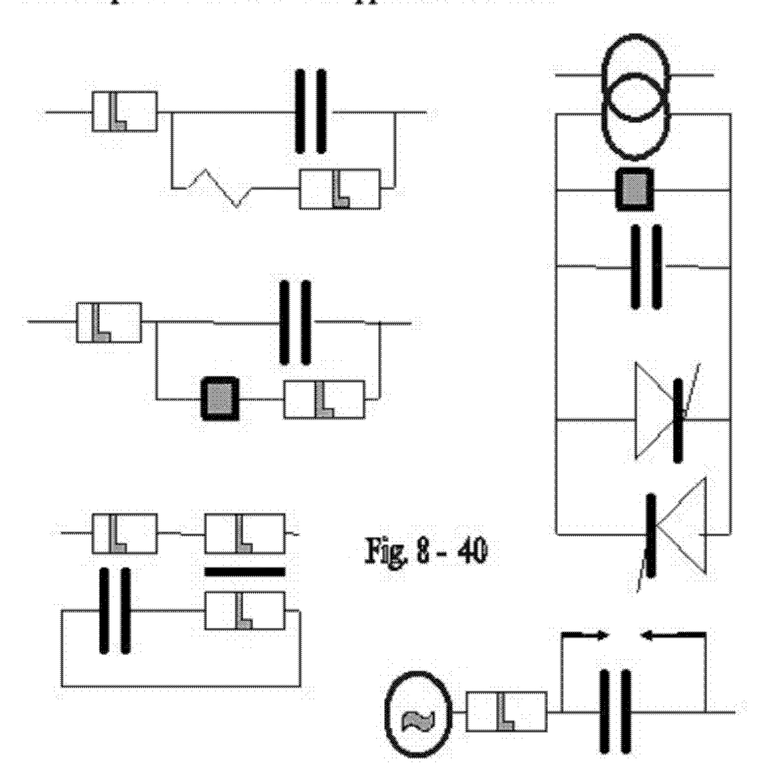


Fig. 8 - 40

4- Limiting current devices

Schemes for limiting current devices may be given for example in Fig. 8 -40 where it must be controlled to limit the short circuit currents during faults. This automatic concept is preferred usually in electric station.

III- Three Wire Diagram (3WD)

any single line diagram can be translated into a 3 wire diagram where the neutral and earthing connection will be appeared. It is the complete view of electric circuit which must be the base in the final revision after design.

However, the SLD is always the first step and the 3 wire must be deduced from it. The SLD is still the main item in the design that would be followed by some other steps. This will be more clear at the end of the given book after the studying all presented important subjects. On the other hand the protection schemes could not be illustrated completely on the SLD while the 3WD gives all details on the drawing.

For example Fig. 8 – 41 , a presents a simple single line diagram which occupies a little area with a small number of lines. Contrary, the 3WD for this single line diagram has been drawn in Fig. 8 – 41 , b where a lot of lines and a compression view may be appeared for the eye. So, the single line diagram is very important to give a complete circuit while the 3 WD may be given for a small part of it to explain any details related to the three phase connections.

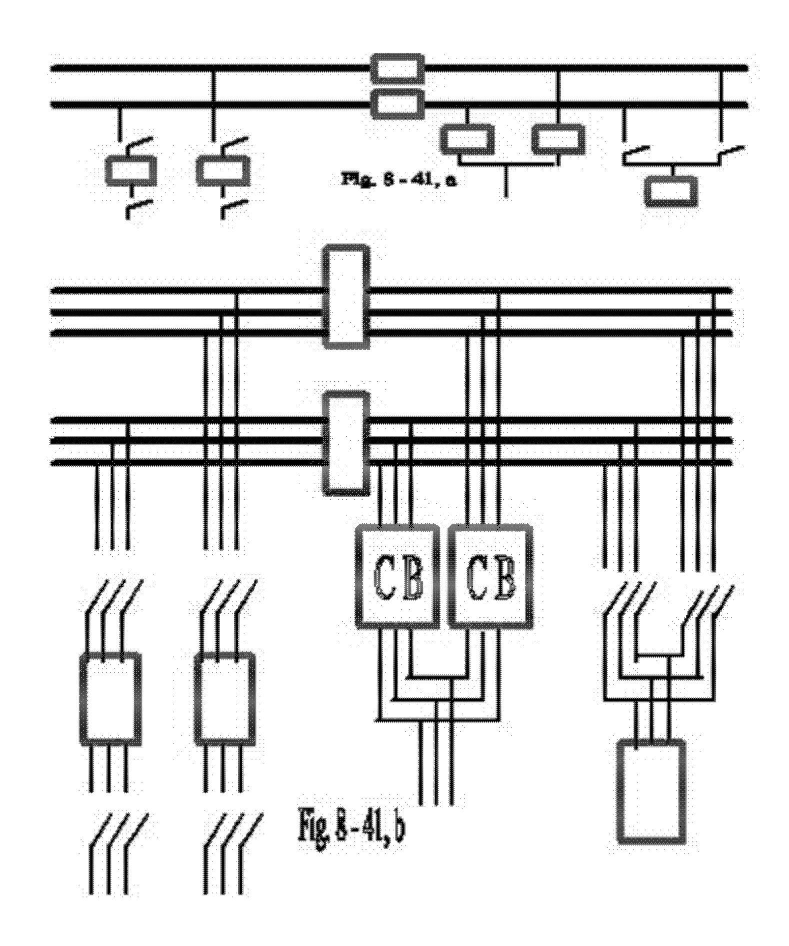


Fig. 8 - 41, a

Fig. 8 - 41, b

BASICS FOR THE LAYOUT

The title of LAYOUT is an important for the designers of any construction but it is very urgent for electric stations from the point of electricity view. This means that the layout of a station must reflect well all components inside and consequentially, the electric devices and tools used. It may be clear if the basics of the layout are studied and explained. Also, this needs some necessary items to be discussed according to the next presentation.

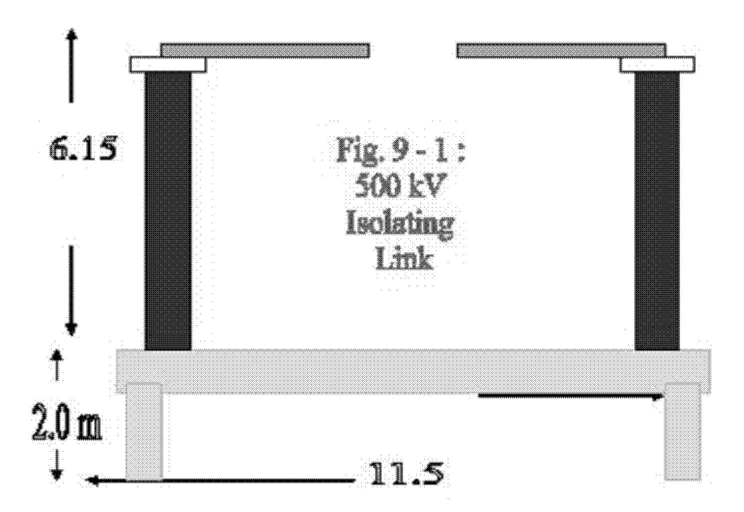


Fig. 9 - 1 : 500 kV Isolating Link

9 - 1: RULES

From the first rule we find the minimum permissible distances for the components in a station in general where Fig. 9 -1 presents the dimensions of an isolating link 500 kV. Also, Fig. 9 -2 (a, b) shows the permissible distance between the edge points such as phase to phases either spacing F or e or K or to adjacent circuit D – phase to earth A

or S or g or n – phases to grounded body S or n .Then, the height of life phases u and cell width d are indicated.

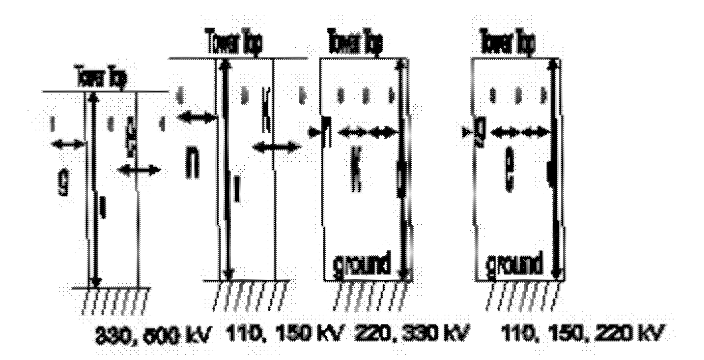


Fig. 9-2 (a)

a
b
B
X
d

Fig. 9 – 2 (b)

The given practical values are listed in Table 9 - 1 where both drawings are considered. These dimensions are a base for the design process.

Table 9 - 1: Minimum Distances, m

Parameter (m)	110 (kV)	150 (kV)	220 (kV)	330 (kV)	500 (kV)
a	8	11.5	11.75	18	29
b	9	9.5	12	19.6	26.8
B	12.5	15	18.25	20.4	29
x	10.5	16	20.5	31.5	45
d	9	11.1	15.4	22	31
e	2.5	3	4	8	11
g	2	2.55	3.7	4	5.5
z	7.5	8	11	11	14.5
u	11	13	16.5	16.5	23.6
k	3	4.25	4	4.5	6
n	1.5	2.13	3.25	3.5	5

Similarly for the shown components in Fig. 9 – 3, the corresponding dimensions are listed in Table 9 - 2.

Table 9 - 2: Minimum Distances for Fig. 9 - 3, m

parameter \ (kV)	10/35	110	220	500
A	0.2/0.4	.9	1.8	3.75
F	0.22/.44	1	2	4.2
S	.95/1.15	1.65	2.55	4.5
Q	.95/1.15	1.65	3	5
G	2.9/3.1	3.6	4.5	6.45
D	2.2/2.4	2.9	3.8	5.75

All dimensions are given for a standard voltage specified but using the interpolation or extrapolation mathematics any voltage

characteristics may be determined. Otherwise, the permissible distances specified in the Table are highly increased with the raising of nominal voltage value. Contrary, with LV values the permissible distances may be little varied.

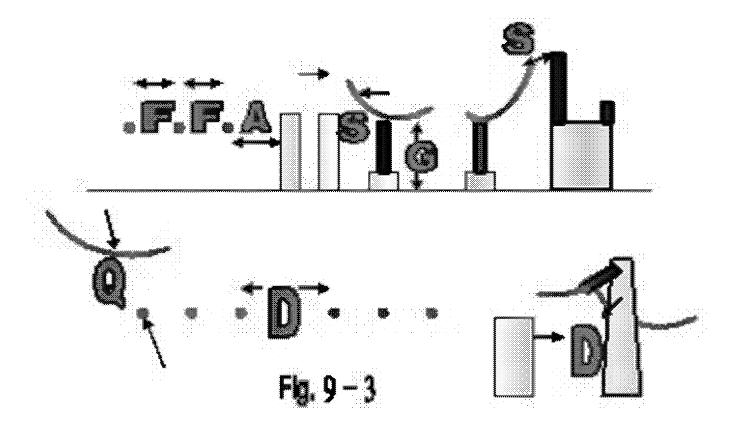


Fig. 9 – 3

It should be noted that the effect of voltage on the allowable distances for the spacing or a crossing circuits or life wires at HV is high but this effect may be a dummy factor for consumer voltages.

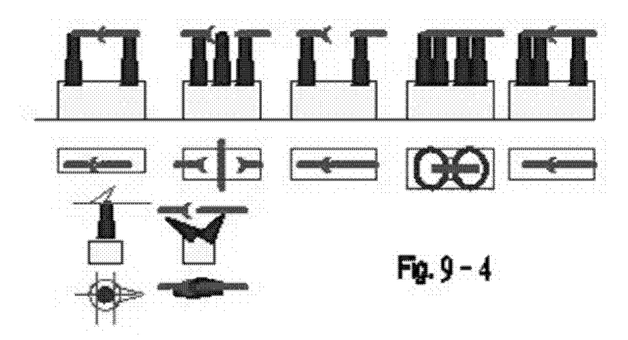


Fig. 9 – 4

These major dimensions for the indoor type of stations are given in Table 9 - 3.

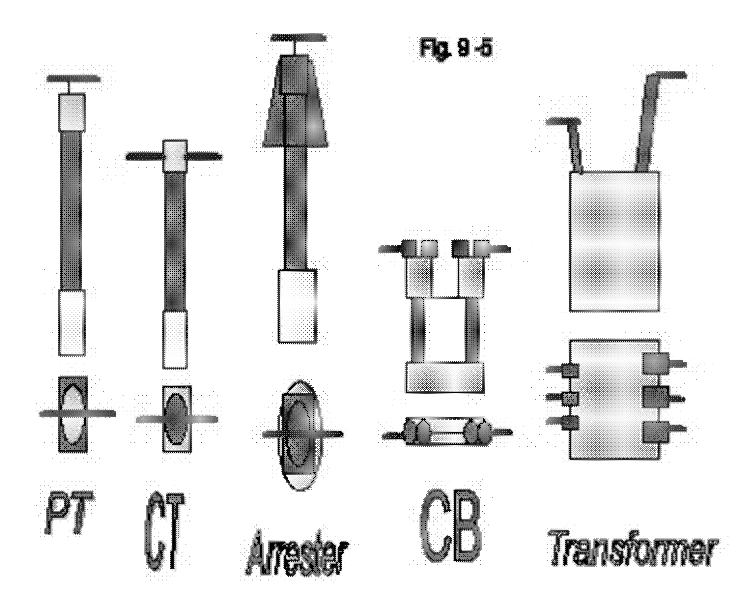
Table 9 - 3: Minimum Distances for indoor cases, cm

kV / Parameter	3	6	10	20	35	110	150	220
A	.065	.09	.12	.18	.29	.7	1.1	1.7
F	.07	.1	.13	.2	.32	.8	1.2	1.8
S	.095	.12	.15	.21	.32	.73	1.13	1.73
Q	.165	.19	.22	.28	.39	.8	1.2	1.8
G	2	2	2	2.2	2.2	2.9	3.3	3.8
D	2.5	2.5	2.5	2.7	2.7	3.4	3.7	4.2
S	4.5	4.5	4.5	4.75	4.75	5.5	6	6.5

The types of isolating links are given as projections for the layout condition, i. e. elevation and plan drawings.
It is notices that there various types of I. L. and to operate as the first moves horizontally. The second moves horizontally with an axis at the middle of I. L. while the third vertically. This means that there are many types that can be chosen for a design application.

9 - 2: MEASURING INSTRUMENT

The Layout Of Individual Equipment for measurement or switching or even protection is a fundamental item in the design. So, the individual layout of the most important equipment is shown in Fig. 9 - 5.
Current transformers have two terminals (Input & Output) while the voltage transformer has only one terminal because the second is earthed through the windings. Also, the arrester is usually, similar to the P. T. while the CB differs from the I. L. in that the arcing chamber is projected as a box. This CB differs from transformers in that the insulation height is the same for CB but there is a difference in the transformer.

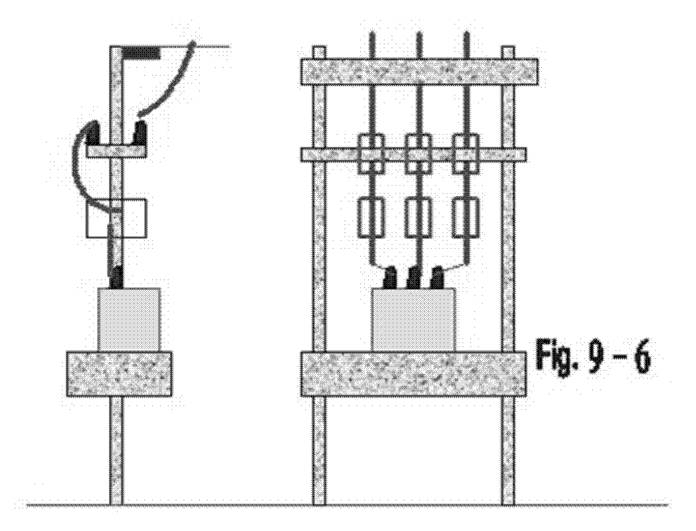


It is important to point that each element or component in the station is given for a single pole type except the transformers up to 500 kV and generators. The single pole style for CT and PT may induce a difficulty degree in the application of protection schemes that must be taken into account during the design practice.

9 – 3: CELLS

A station must be divided into some equal zones where each zone should be responsible for all connections for a certain item such as entrance of a transmission line or feeder or even others. This means that the station will take a rectangular shape in which many small rectangles (cells). This seems to be a simple illustration for the layout. So, each cell means an individual connection that should be ended at the BB inside. The given style of cells is acceptable for both types of stations indoor or outdoor as well as the panel system.

It is practically used for the typical type of stations specially for the small power distribution stations. It can be tailored for different levels for example as written next.


Fig. 9 – 6

I- Terminal Steel Structure Stations

Terminal steel stations are the most practical construction for the low power supply for the distribution networks. This type of such stations can be illustrated as the steel structure units is the base as given in Fig. 9 - 6 for a typical 6 / 10 kV distribution station or single portal 35 kV station. This is drawn as shown in Fig. 9 - 7 and also, for the HV stations. The HV stations may be taken for example the typical 110 kV S. S. of Fig. 9 - 8 (a) and the steel typical 140 kV S. S. as presented in Fig. 9 – 8 (b).

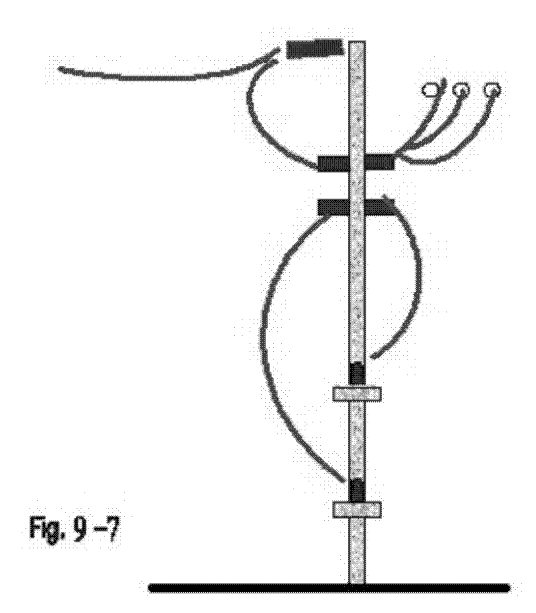


Fig. 9 -7

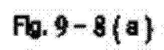
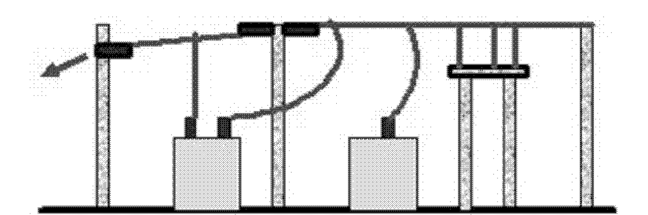
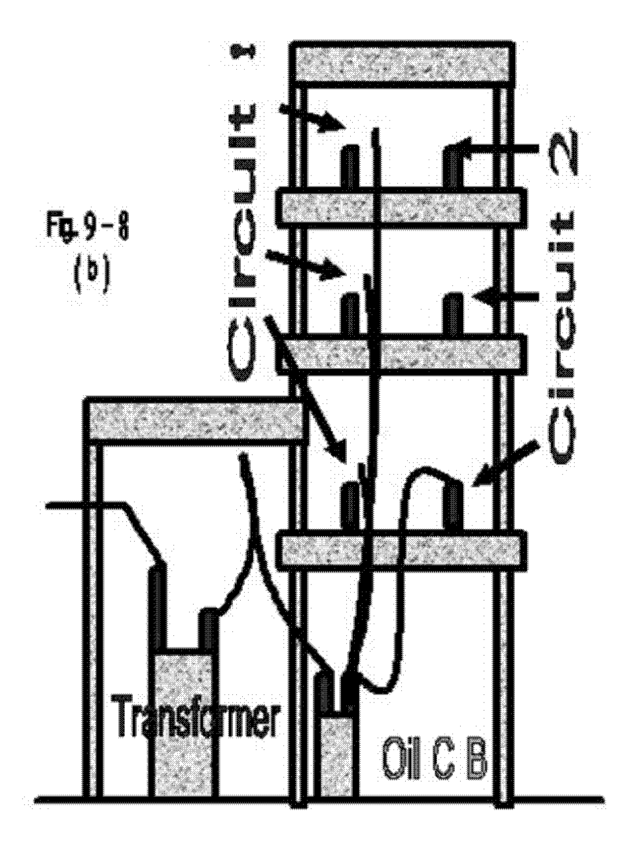


Fig. 9 - 8 (a)





II- Outdoor End Stations

However, the terminal stations as well as the end stations are important the distribution of the consumed power at the consumer place where it is very important to use the transformers and underground cables. This will raise the safety factor and may prevent many of external faults.

It is clear that the abroad of cities may leave the outdoor available but under the restrictions of human security for operation and others. This means that the regulations for the installation of such stations must be considered for safety rules according to the specifications. On the other side, there are simple units can be considered as:

1- Basic diagrams

Since the commercial style for the production of electric stations is considered, the SLD has been given as a standard for the same requirements. Then, the standard schemes simplify the steps of a design so that the designer may need only a good selection between some of the tabulated schemes. All of the basic schemes are working well and consequently, one of such basics SLD has been shown in Fig. 9 – 9.

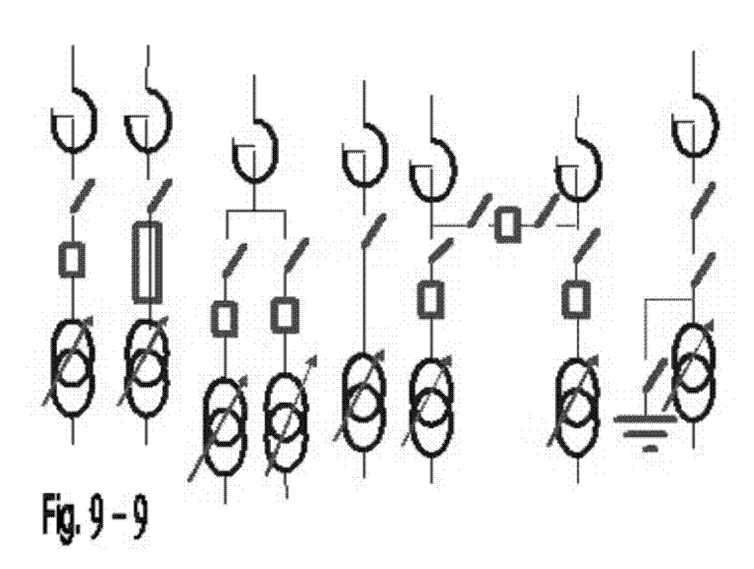


Fig. 9 – 9

It is shown that a short circuit reactor is widely used in the scheme that demonstrates that the station is located at a high level of short circuit.

a) A 6.5 MVA Unit

However, the terminal user distribution substation may be a station unit as given in Fig. 9 – 10 where the lay out explains well the distribution of wires of phases in the space coordinates. It is a cell for a distribution transformer which may supply a cable end at the LV side. Whatever, the given strategy for uniting the parts of a station will simplify completely the process of design as well as the visibility study.

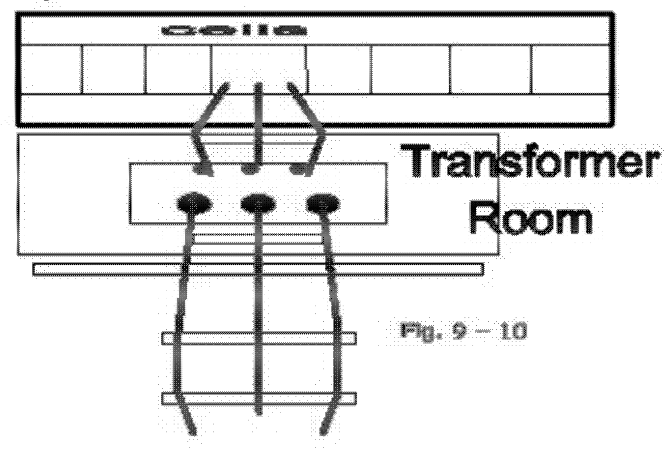


Fig. 9 – 10

b) A 1.6 MVA Station

On the basis of unite strategy for the parts in a station, a complete small station may be considered. Also, it may be utilized for the same power at the same operation performance in any electric power system specially at the terminal user. Thus, a lay out of a small station 1.6 MVA as a unite may be put for example in Fig. 9 – 11.

It is working at a nominal voltage of the normal consumers (0.4 kV).

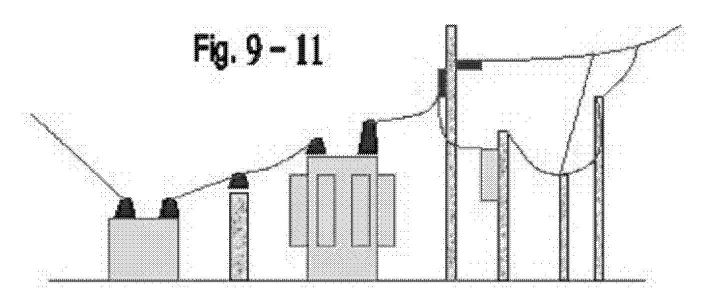


Fig. 9 – 11

c) (Out / In) door station

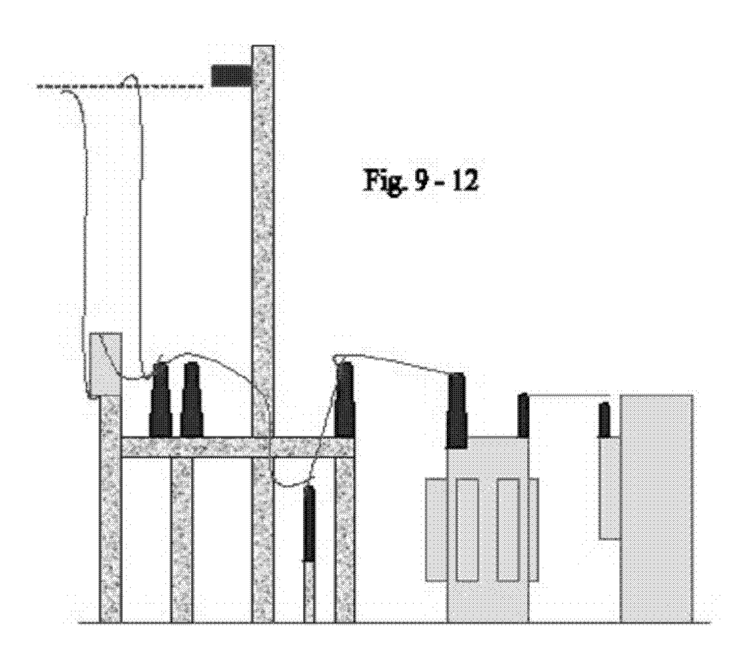
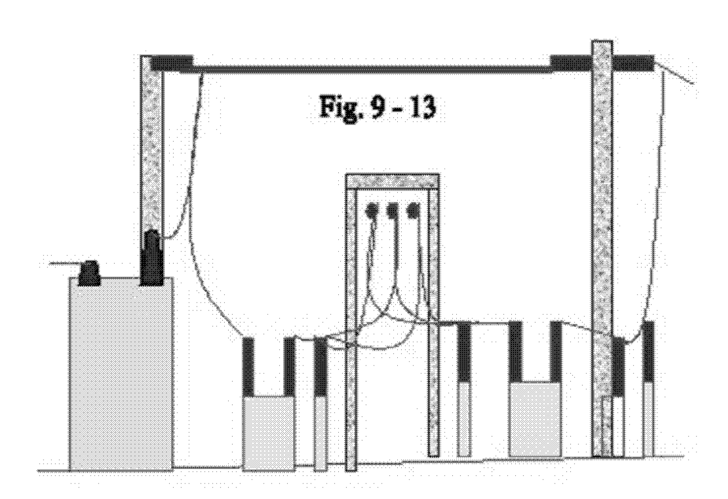


Fig. 9 - 12

There are some standard stations that can be constructed either indoor or outdoor and then, a great save for area will be reached. This type of stations may be simulated as a layout as drawn in Fig. 9 - 12.

2- Double unit terminal station

Therefore, a unity partition may be collected in a multi number of a single one where the lay out of a double unit (2 x 6.3 MVA) feeding station is illustrated in Fig. 9 -13. The wiring projection would be repeated fro each unit as well as a repeated units will raise the experience besides the saving of area occupying.
This group of units can be repeated easily with the standard dimensions and on the same sequence of arrangement for the elements of a cell. It should be said that the height of a portal is very high according to the permissible distances given in the Tables above while this height will consequently save the area of land occupied for this cell.


Fig. 9 - 13

3- A 35 / 6 kV feeding (Out / In door) type

On the other side, the application of low level distribution cells or even the equivalent small stations would be a simple standard form for a distributing power terminal station. This concept will be classified for either the electric connection or for some shapes and their projections as a layout in the following items.

a) Basic circuits

Therefore, a logic engineering standard for the 35 / 6 kV type of stations may use the fundamental circuits as a base for the connections of the different circuits as given in Fig. 9 -14. This figure may help in the simplicity of the design process because it put the circuit on the basis of a tabulation system. This circuit is valid for either in door stations or the outdoor ones.

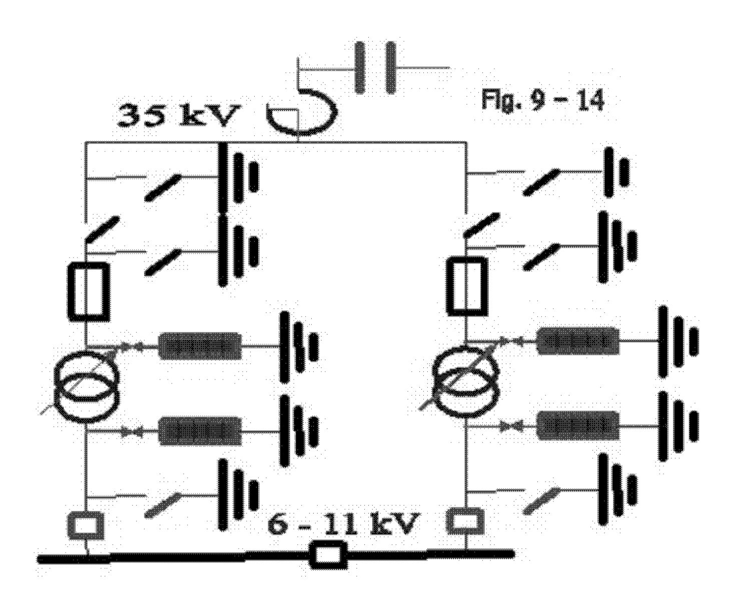


Fig. 9 – 14

b) A single unit

Otherwise, the single unit connection at the same voltages may be applied as a unit as it is presented in Fig. 9 – 15. The single line diagram illustrates the importance of use of arresters at the terminals of windings of a transformer as it was indicated too in Fig. 9 – 14.

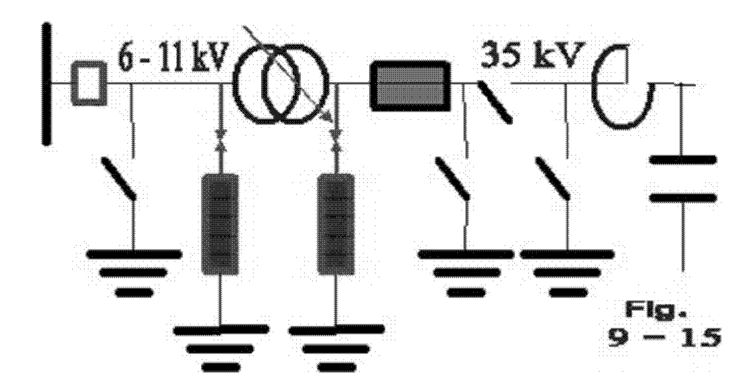


Fig. 9 – 15

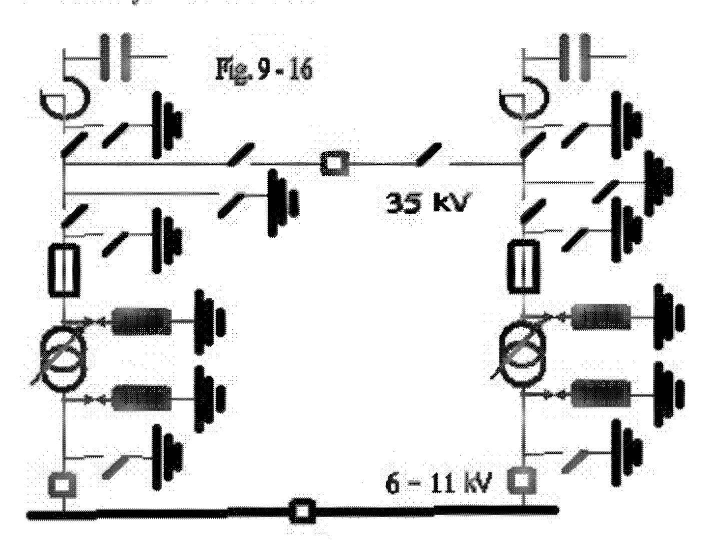
c) Double unit groping

When the unit is repeated we get a multiple groping for this unit. So, for a double unit group the single line diagram has been drawn in Fig. 9 -16 where earthing rods of an isolating link are illustrated as on the figure.

4- Outdoor 0.4 kV supply

The voltage level of distribution at the consumer terminal becomes 0.4 kV at its output power BB when its phase to ground will be 220 V. This supply is the general one used around the world in all networks in spite of some little cases.

Then, a typical formulation for the single line diagram as well as the layout may be a standard for each one. Therefore, some typical circuits may be tailored next.



a) A 11/0.4 kV station

Each 11/0.4 kV station unit is defined as a Kiosk if it is a terminal station of indoor type while it is a portal type for outdoor style. The typical layout for the outdoor 11/ 0.4 kV station is given in Fig. 9 – 17 but the here is hanged or supported on the portal itself. This case for in door station will differ a little.

b) A 35 kV transformer cell

The distribution stations are normally either at 35 kV or at 11 kV and then they may be illustrated. Both of them will be the same without any deviation except the permissible distances as tabulated above. The 35 kV transformer cell as given in Fig. 9 – 18 represents both cases for generality of the proposed subject. Elements of a transformer cell may be seen in the figure according to the logic partition style.

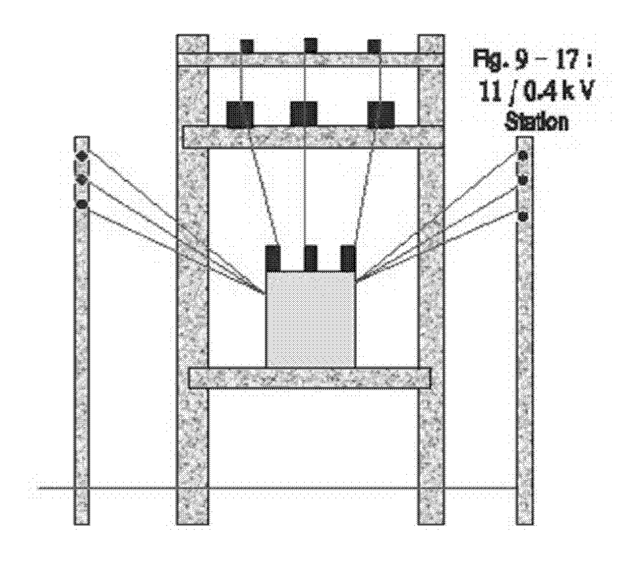


Fig. 9 – 17 :
11 / 0.4 k V
Station

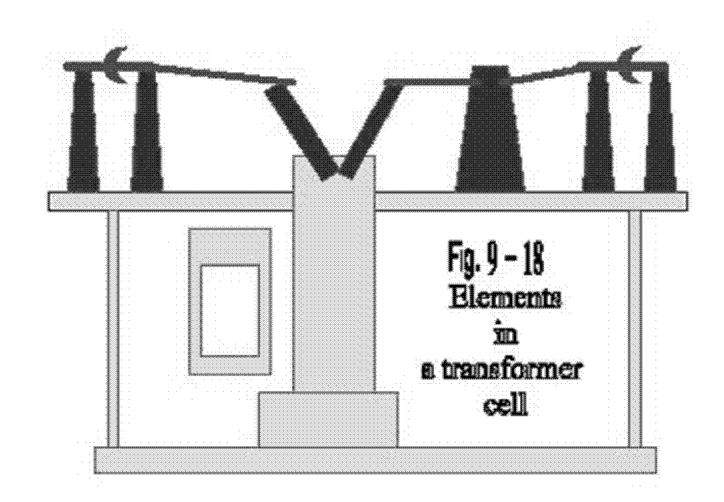
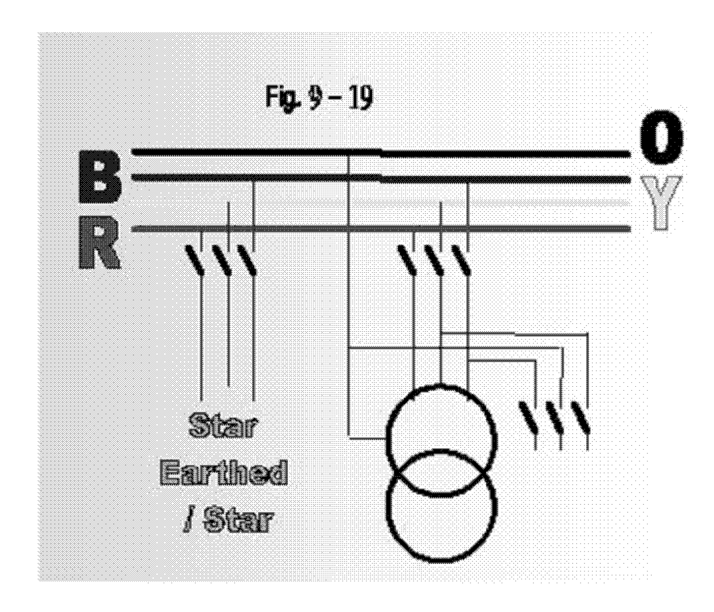


Fig. 9 – 18
Elements
in
a transformer
cell

c) A 11 / 0.4 kV supply

It is a basic information for the electric engineer in the field of distribution networks that the supply unit must face the consumer requirements. Also, the voltage at the consumer must be that of the nominal tools and devices to be used so that the 11 / 04 kV supply may be illustrated as given in Fig. 9 -19.



d) A 1 MVA Panel

Therefore, according to the concept of work in this book the distribution panel represents an element in the unit system and so, the lay out of a switch board may be needed where one typical layout of a supply panel for example is given in Fig. 9 - 20. The cable end is shown and its connection to the BB of the panel.

The switch board has a rating for the power it carries because this rating reflected on the dimensions and distances of the board. The details of fuses and supports of a BB as well as connection points are shown too.

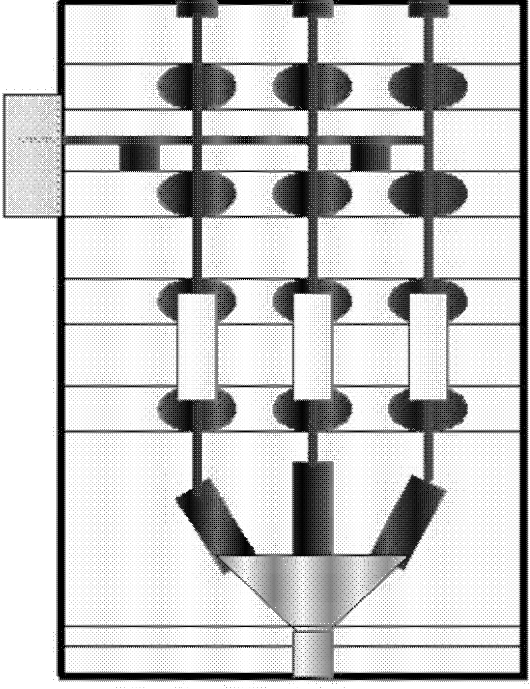


Fig. 9 – 20

Otherwise, for the HV distribution station such as 110 / 04 kV stations or 66 / 0.4 kV distribution stations the same lay out is presented but with a larger distances according to the tabulations.

Then, a typical layout for the distribution part in a station is indicated for a 110 kV, 6.5 MVA distribution station in Fig. 9 – 21 where a simple layout can be remarked.

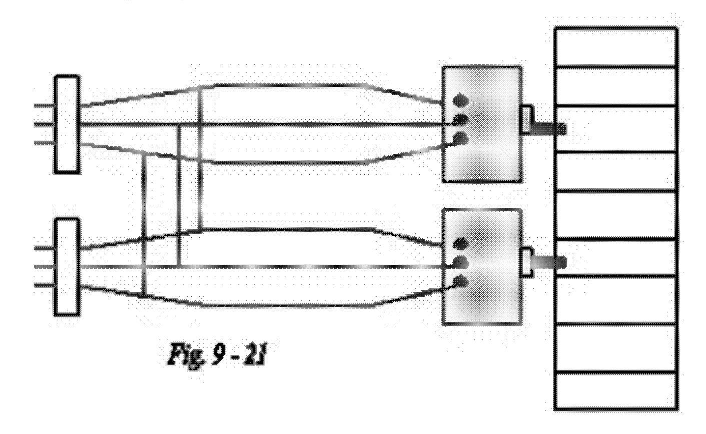


Fig. 9 - 21

On the other side this may be repeated for the block style as given in Fig. 9 - 22. It should be noted that this block uniting may be repeated for all types similar stations in spite of the difference in the voltage level.

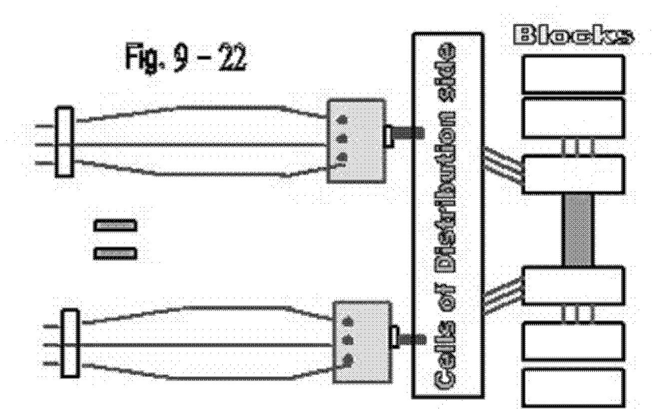


Fig. 9 – 22

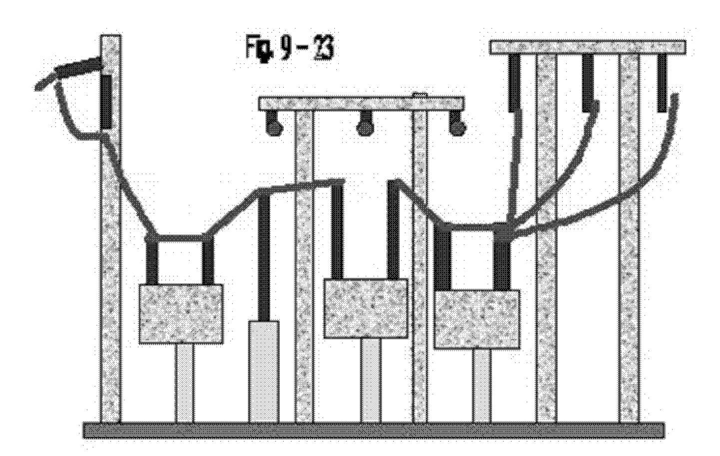
All the given circuits and their layouts are presented for the sample purpose in order that the next discussion for the design process may be more simple.

III - High Voltage Stations

It is known that the HV level in a power system will be very necessary for the transmission purpose because this reduces the power loss in feeding a load. So, a HV stations will be found always in a power network so that its study will be a positive point in the subject concern. This type of stations may be for example classified and then they can be illustrated through some typical stations according to the voltage level as follows.

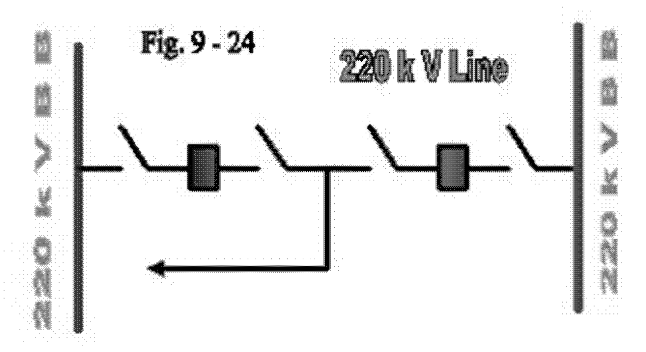
a) A 110 kV Sub Station

For outdoor stations this level of layout may be presented for illustration as drawn in Fig. 9 – 23 where the wiring configuration can be seen well. This sequence of connection is important to understand as a logic principle for the general design.


Fig. 9 – 23

b) A 220 kV Switching Station

The switching stations are a special type in a network because its need may be rarely appeared. It can be used at the junction between two united power systems or inside a network at a certain special positions. Then, for a 220 kV level a switch station may be appeared in Fig. 9 – 24 where double sided station can be shown. Thus, each BB at each side will be connected to a transmission line or cable. Sometimes, the two sides of a station can be connected one to transmission line while the other will be connected to a cable. Also, the location of such a station may be outdoor or indoor due to the simplicity of its components.



c) A 330 kV level

Although the 330 kV expresses the HV level, a power station can be connected to a network on such voltages. Fig. 9 – 25 presents the SLD for a power station at output voltage of 330 kV while different cells of transmission line have been illustrated. A double BB (non-sectionalized) has been used where a typical scheme is given.

This may be in more detailed schemes as:

i) The Single Line Diagram

The electric circuit as a single line diagram may explain all contents of the scheme while Fig. 9 – 25 illustrates such a single line diagram for a station.

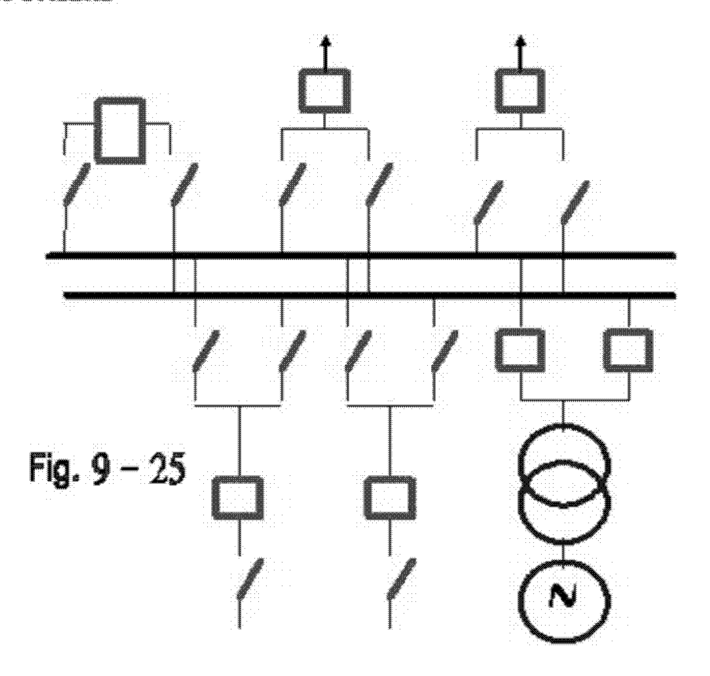


Fig. 9 – 25

ii) A Line Cell

The wiring of a line cell consists of conductors addition to end arrester, a potential transformer, an isolating link, a current transformer, a circuit breaker, junction point, double isolating links and finally the double bus bars, respectively. This is given as a single line diagram for a transmission line in Fig. 9 – 26 while its lay out is presented in the same figure.

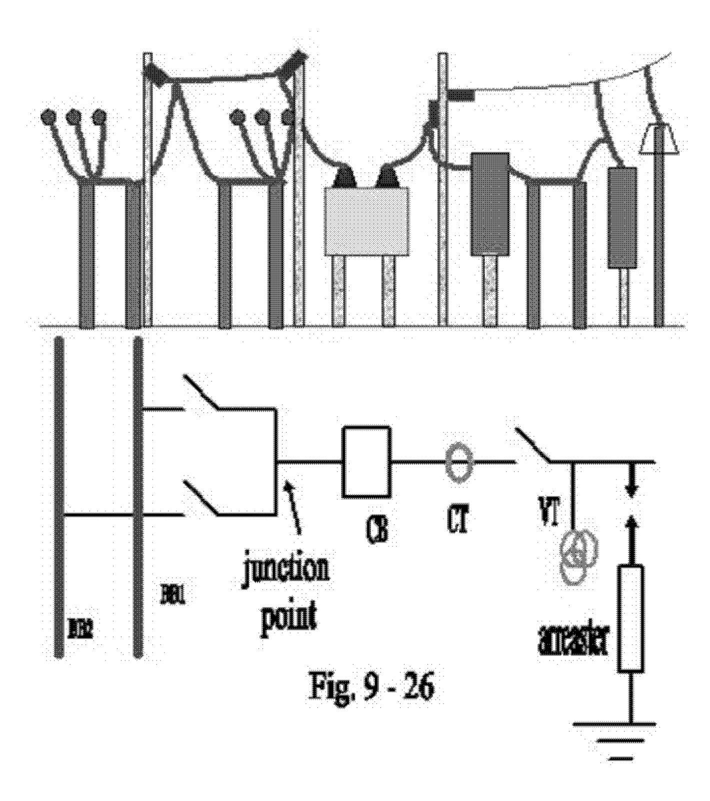


Fig. 9 - 26

iii) A Transformer Cell

A transformer cell may be one of the most important cells in a station because the transformer is always located at the other side of a cell. This will give the cell more importance where the target would be the saving of area occupied. The single line diagram of a Transformer Cell may be seen in Fig. 9 – 27 where the connection is very simple.

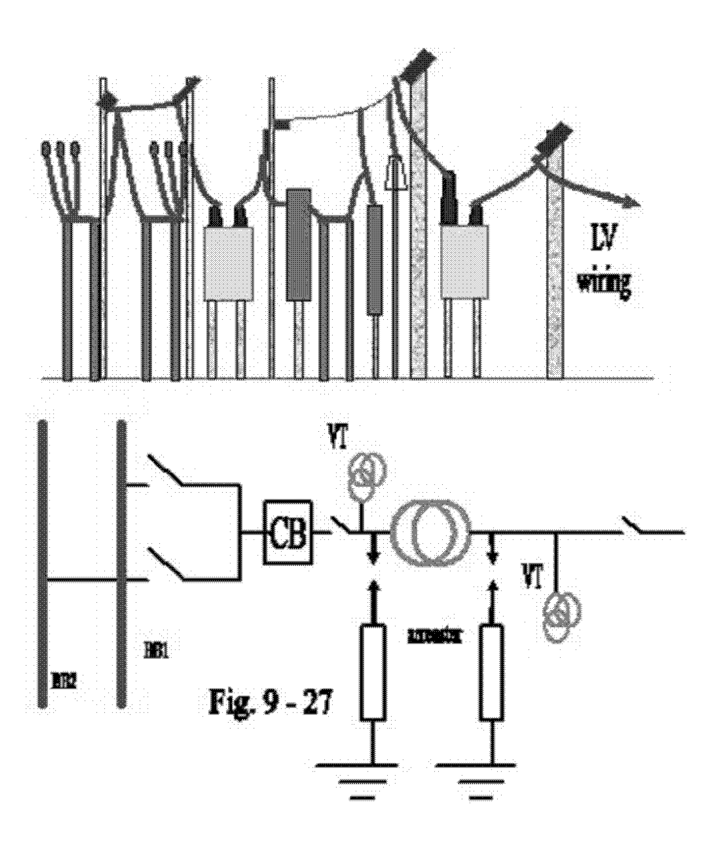


Fig. 9 - 27

However, it is seen from Fig. 9 – 27 that the transformer cell will occupy a complete area for the cell where lines must be adjacent without any overlap. The sequence of components may be at a center line differs from the line cell as shown in Fig. 9 – 28.

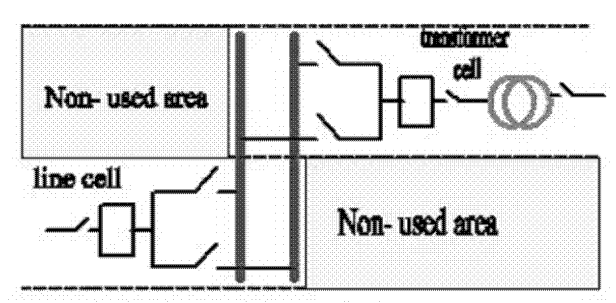


Fig. 9 - 28 Single line diagram

This expresses a problem from the engineering point of view that leads to a new solution in order to reduce the used area. The given layout for both cells of transformer and line in Fig. 9 – 29 proves that it is a great problem due to the area consumption without its utilization.

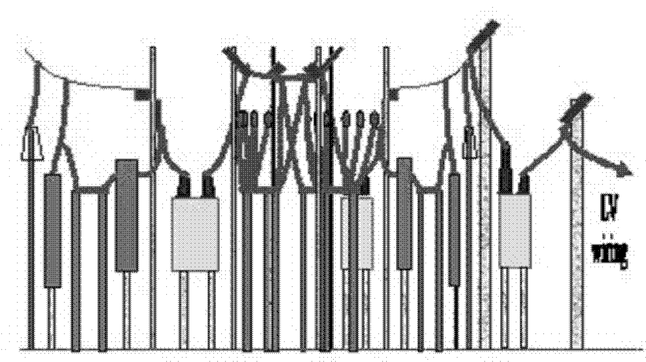


Fig. 9 - 29 : Lay out of line and transformer cells

iv) Principle Dimensions

The major factor for a good design is the low cost where any increase in the area needed will take a raising in the total cost of the project. Thus, the results may be drawn in Fig. 9 –30 where the lay out will be similar and parallel completely to the line cell as given in the single diagram. This is a right tendency for the engineering design of an electric station.

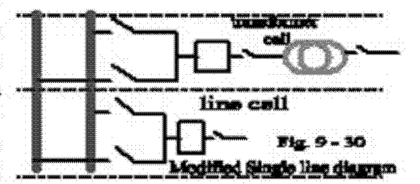
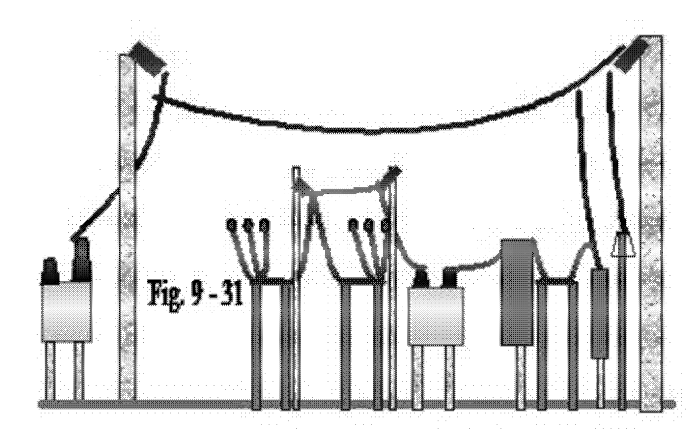


Fig. 9 - 30
Modified Single line diagram


Fig. 9 - 31

This will give the view of harmony distribution for the components of each cell which is registered as one of the basic rules for the design of a station. The non-used area is disappeared completely (Fig. 9 – 30) and the cells are parallel together (each to the others) where the components will be similar on the basis of harmony.

Therefore, a new addition must be done to make the direction of components in the transformer cell like that exactly of the line cells. Consequently, a third height would be necessary in order to begin the connection on the same way of line cell as well as to similar. This is shown in Fig. 9 – 31 where the same above lay out has been crossed above the connections in the same cell of a transformer.

d) EHV Yard layout

Similarly, a basic style can be considered for EHV and UHV levels as above such as 500 and 750 kV, and consequently, the logic view will be the same. However, a major classification for this view may be tailored in the following form inn titles as:

a- Line Cell.
b- Line - transformer Connection
c- Double CB
d- Triple CB

All these items may be illustrated and so treated as said above but only difference will be that the isolating links must rotate in the vertical direction instead of the horizontal axis for less voltages. The spacing is a control factor for such layout projections.

Chapter X

LAY OUT DETAILS

As explained in the last chapter about the lay out of a station or a component inside while the single line diagram of this station (or its part) can be given as a major factor for the layout. Otherwise, the layout would be expressed through the engineering projection for the connection electrically on a civil projection. Therefore, the layout may be given as the three projections as: Elevation, plan, and side view. Actual layout would be the interest of the designers since it is a part of the design while the main basics have been explained in the last chapter. Generally, this subject will be of worth value when it includes both types of stations as power stations and substations. However, the details may be presented through some examples for illustration.

This sampling concept would be a good tool for comparison between different designs. Thus, the presentation for a lot samples with different styles of logic design idea may help in raising the quality of this design. Therefore, some basic details for electric stations according to their type will be presented and analyzed. This chapter deals with the comparison basics for power stations as well as substations.

Hence, drawings and pictures may help in understanding the goal of proposed items. On the second side, we must indicate that plan can be given for a cell or for the station as a whole or for a part inside but both elevation and side view may be given only for a cell as a section inside the components of this cell. More details should be proposed and discussed for the complete explanation of the subject.

10 - 1: POWER STATIONS

Real stations as a layout may vary in a wide rang depending on the type of the station. This will be clear with the hydro type power plants or that of the thermal fuel base or those with the bulk power atomic energy. The layout for both hydro-power station and the

thermal stations will be presented in the next paragraphs.

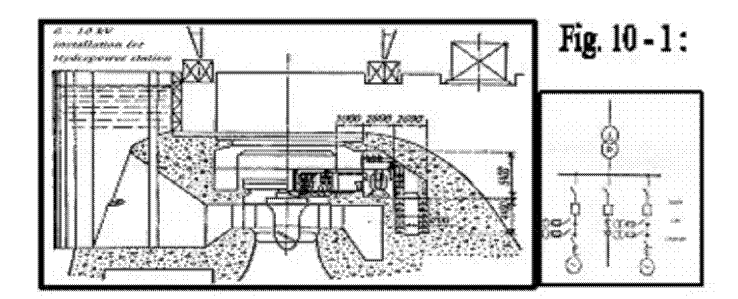


Fig. 10 - 1 :

1- Hydro power stations

The hydro power station is the most cheapest type between all and it is characterized through the multi level for the HV installations as given in Fig. 10 - 1.

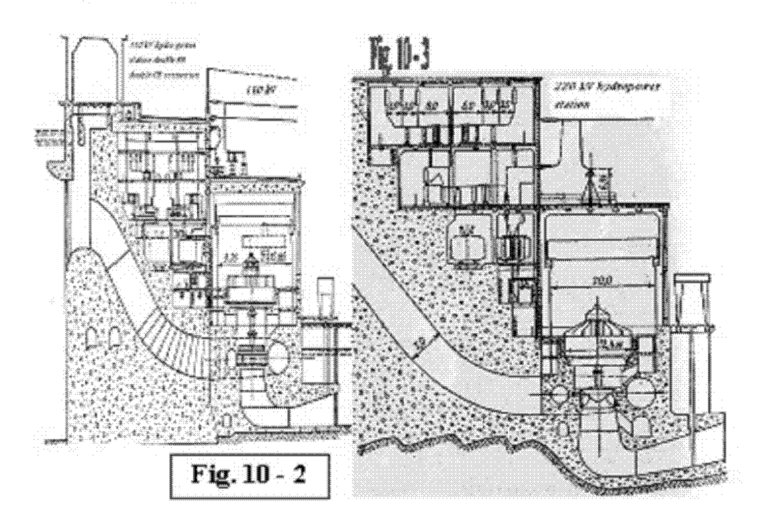
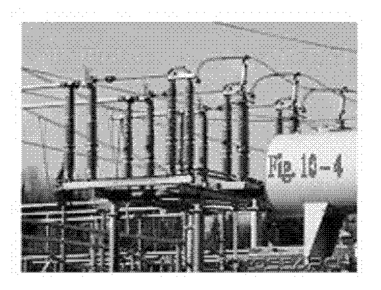


Fig. 10 - 2

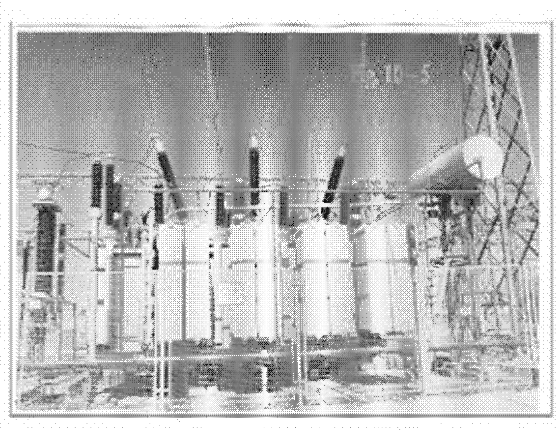
Fig. 10-3

This figure presents a sample for a typical station. It is a typical 6-10 kV as shown in the single line diagram where triple units are connected to a single transformer.

The single line diagram is given for a station and the lay out of a turbine location is shown. The soil as well as the turbine itself are presented in the lay out as a civil section in the site. Accordingly to the given shape, a good design for the wiring at HV level can be deduced. Such plan leads to a good layout for electric design. Although the land in the site at turbines has a special characteristic, a good engineering management for the place can be achieved.


Fig. 10 – 4

On the other hand, Fig. 10 – 2 presents another shape for the 110 kV level of voltage. It is based on the double bus bar system with double circuit breaker operation as shown. The optimal utilization for the area is shown where the non-horizontal shape of land.


Fig. 10 – 5

A step type of arrangement for the conductors at high voltage has been selected in spite of the various possible solutions.

However, the voltage level raising, to a 220 kV for example, needs the best choice for the area management while it can be too realized by

more extension. Then, this layout can be shown in Fig. 10 - 3 for the 220 kV installation. This installation consumes a large area as the shape of such lay out can be shown for example in Fig. 10 – 4. It is a small part of the switch yard while the transformer itself may be presented alone in Fig. 10 – 5. In this figure the overall layout for the site where the power transformer is located is shown in Fig. 10 - 5. On the other hand the side view for such a layout may be deduced according to the power transformer shape as given in Fig. 10 - 6.

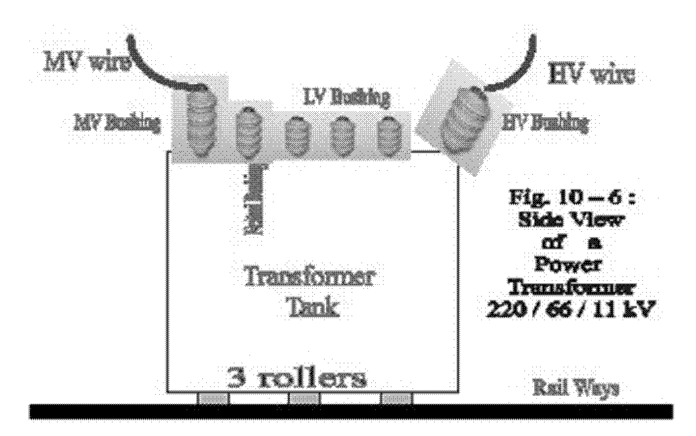


Fig. 10 – 6 : Side View of a Power Transformer 220 / 66 / 11 kV

This side view shows the LV side where 3 bushing of 11 kV and the neutral bushing which connect the neutral point of star windings of a transformer to earth. Also, both bushings of HV and MV are appeared as a one insulator for the 3 bushings. Thus, the side view is important because it shows some elements – not seen from elevation. The complete side view must clarify the side contents such cables of LV (or MV level) and radiators as well as thermometers and others.
However, a steel structure my be the solution for the best utilization of the place performance so that a simple structure as shown in Fig. 10 – 7. It is a support point inside the non-horizontal land and consequently a land saving will be reached.

2- Thermal Stations

Contrary for the thermal types of power station such as steam or gas power stations, the layout is typically standard in shape due to the almost horizontal land surface. Fig. 10 –7 showed the first variant for a 110kV cell while the shape of an

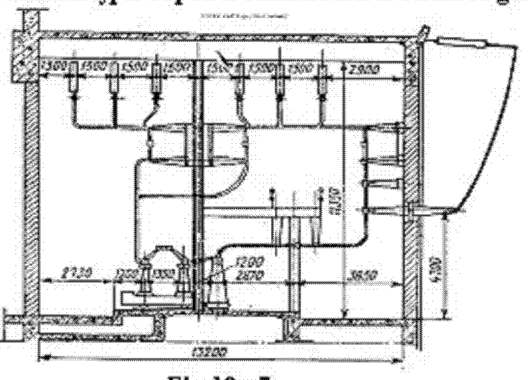


Fig. 10 – 7 :
Steel construction layout

indoor power station is given in Fig. 10 - 8. A second connection for the thermal power station or even for the hydro power stations as a support for the low voltage connections is similar to that of Fig. 10 - 7. All of these cells are of the steel style for the portals used. This picture shows the HV wires at the top as well as they were coming from the wall bushings at the side of the building. Therefore, a side view for the building can be done easily since understanding of every thing (element or part or connection). Secondly for both



stations (hydro or thermal), an internal connection may be very important to fit a design because some items would be saved such

area of land, quantity of materials, power loss during operation, reliability, and all other fundamental factors of design. Therefore, a bus bar connection may be valuable as it is given in Fig. 10 – 9 where a pipe bus bar has been used. It should be marked that the BB does not evacuate the area under it but a good utilization for the area has been applied. This means a saving not only for the area of the station but also for the conductors used and consequently the loss in them.

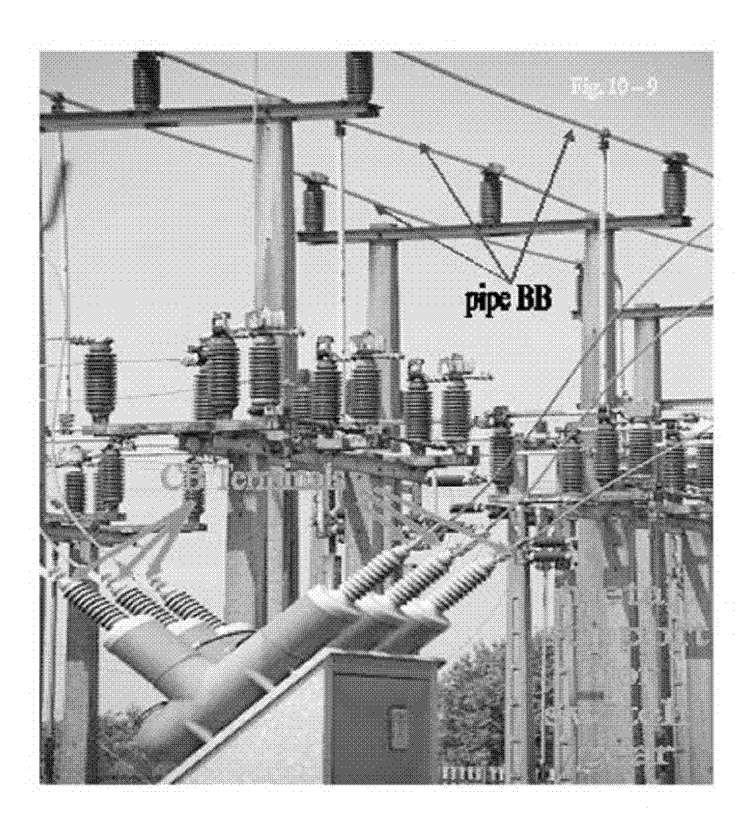
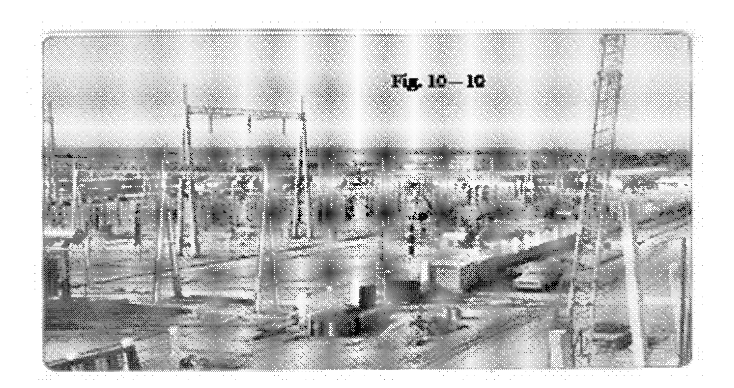
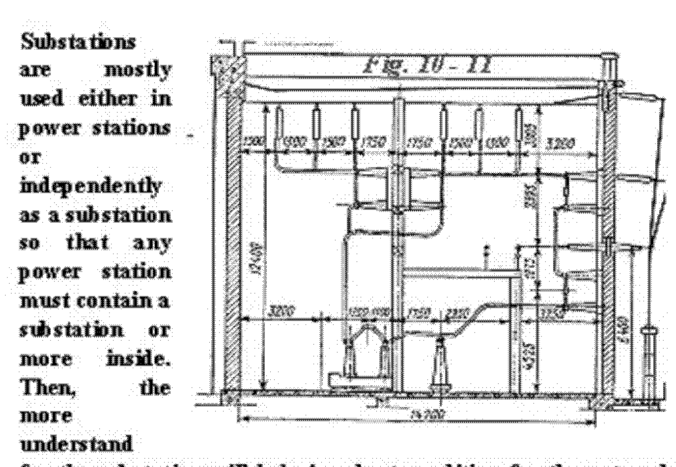


Fig. 10 – 9

10 - 2: SUBSTATIONS





Substations are mostly used either in power stations or independently as a substation so that any power station must contain a substation or more inside. Then, the more understand for the substation will help in a best condition for the network as a whole. This means that substations are widely installed in a network with respect to the power stations. They are implemented at the terminal of users too as well as at the buses of all alternators in it

besides the intermediate cases. Thus, substations would be classified here in the following concept in order to simplify the understanding goal of this book.

1. High Voltage Substations

Generally, the HV substations are the most spread type of all stations in a power system because it must be a part of any power station connected to the network. This means that their presence is the same as power stations in addition to the required stations to raise the voltage of transmission plus that stations receive this transmitted power at all centers of consumers. Thus, HV substations become the most popular stations so that their study will serve all

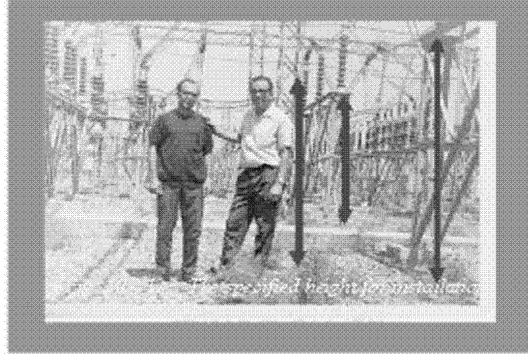
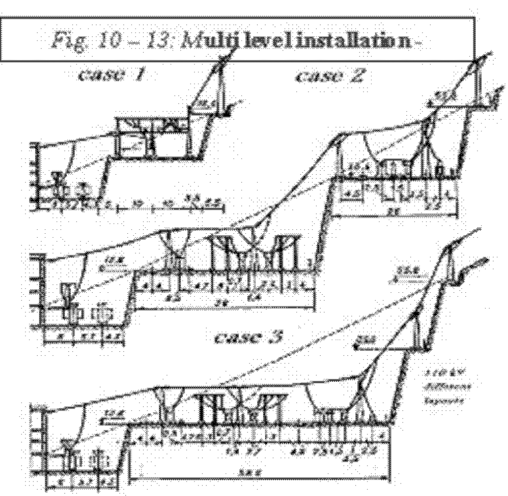


Fig. 10 – 13: Multi level installation -



types of stations. These stations may be given as a general view in Fig. 10 – 10 where the harmony and all other parameters of the design basics are considered.

It is in Fig. 10 – 11 that the steel structure is a good tool for the implementation of stations because:

a) Low cost
b) Small space
c) Good natural ventilation
d) Short conductors use
e) Simple bolting system

220 kV varient layout

Fig. 10 - 14

Therefore, for more illustration the specified height for installation above the surface of land is indicated in the picture of Fig. 10 – 12 where the base of all installations in a station must be above the possibility of human in the site. Then, a maximum tale of a person of 2 m in addition to his arms may be considered with a practical tolerance. This is the minimum length of a base where it may be about 3 m. Practical results are usually collected and then

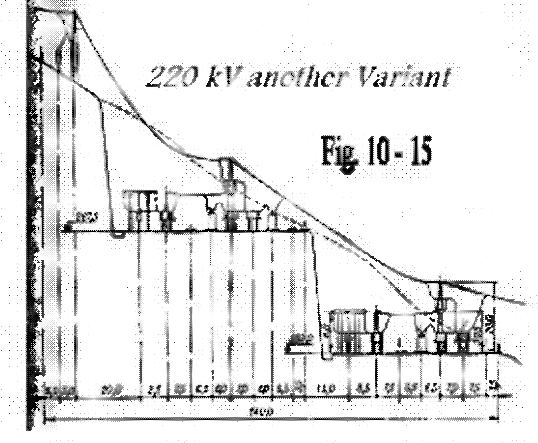
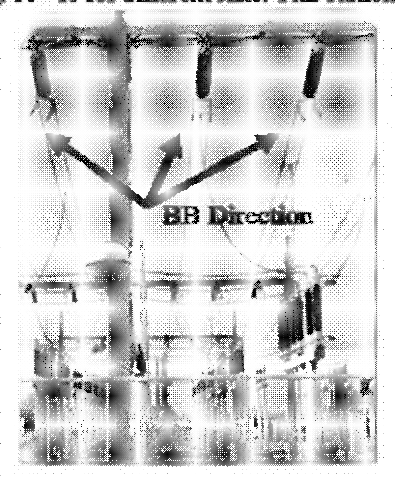


Fig. 10 - 15

tabulated for help as well as guiding.

On the other hand, the geographic fact for the land of a station does not help for the installation of such station on a horizontal land so that a multi level station may be the practical solution. This situation may be a fact for the station on dams or the places on hills and others where a design for a station would differentiate between all possibilities. Whatever, it is given a layout for the multi level installation in Fig. 10 - 13 for a station at the same voltage level 110 kV switchyard with three different variants where this condition may be appeared in the mountains or even in new places where the land is not flat as shown in Fig. 10 - 13 for different sizes. This station has 3 different area with a suitable 3 variants as increase in area permits more elements for addition.



This explains the difficulty for the installation in different levels due to the sag variety and the specified spacing with ground as cleared from the heights above surface of Fig. 10 – 13 case 3. The persons under the HV wires as shown will be considered in the cases of the different cases of lay out as in Fig. 10 - 13 case 1. This also, can be shown in Fig. 10 - 13 (case 2) for the passing of cars and equipment under the wires either for installation works or the operation conditions as in Fig. 10 - 13 (case 3).

In other words, Fig. 10 - 14 presents another case for increased voltage at 220 kV installation where more wide area would be needed. Consequently, another variant with other shapes for the same case may be given for example in Fig. 10 - 15.

Also, the multi level installation, generally, depends mainly on the geographic characteristics of the site. This leads to the sag restriction

as well as the line of installation as indicated in Fig. 10 – 13 , Fig. 10 – 14 and Fig. 10 – 15. Contrary, it is important to illustrate that the wires locations of a BB would not depend on the geographic performance because it takes the perpendicular direction for the components of a station.

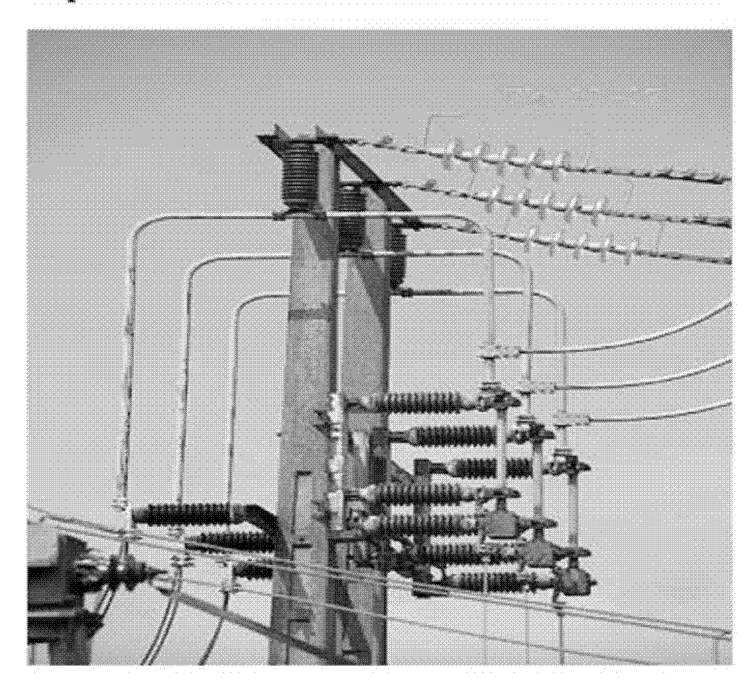


Fig. 10 – 16 may clarify this idea where the BB direction is shown in the top of this picture. In such situations and to overcome the problem of sag, the pipe BB types may be preferable for application as shown in Fig. 10 -17. As the BB is located at the wide of an area its type (wire or pipe) may not represent a significant meaning where all other wiring crossing the edges would have a piping style.
Otherwise, a horizontal land would be the best due to the simplicity that can be achieved as shown for example in Fig. 10 – 18 for a

longitudinal lay out for a small station where the elevation is given.

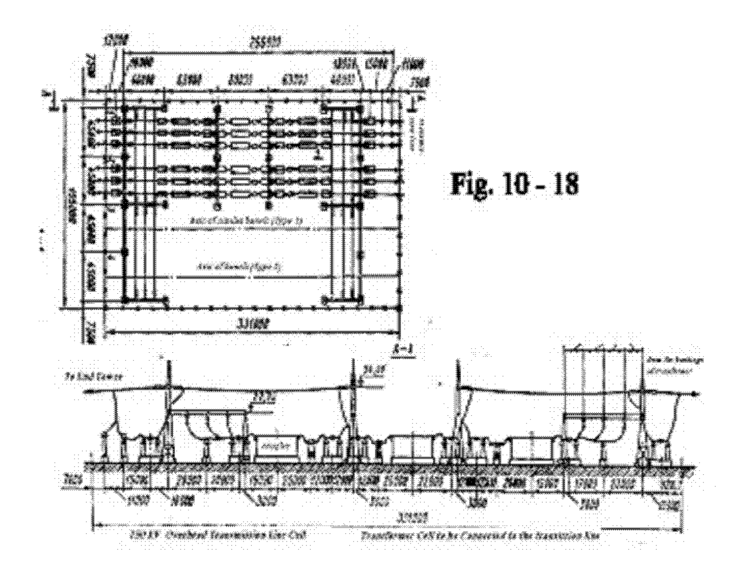


Fig. 10 - 18

Figures 10 – 16 and 10 – 17 put the shape of the axis for equipment in the layout. This photograph may help well in the design of the overall of the layout for the station as a whole. Also, Fig. 10 - 18 and Fig. 10 - 19 shows the first case for a 750 kV for the connection between the transformer and the transmission line and give the single line diagram for the case of single circuit breaker utilization with its lay out.

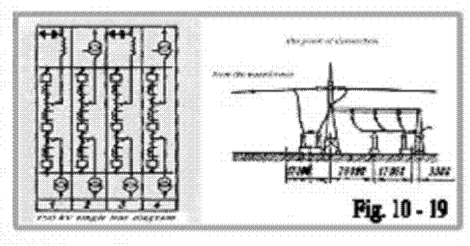
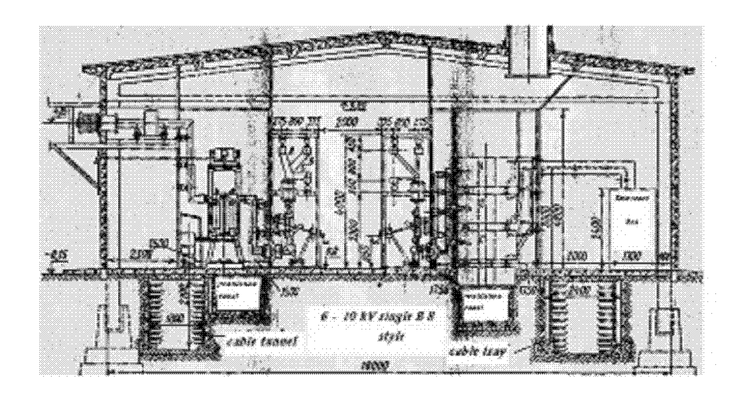


Fig. 10 - 19

2. Low Voltage Distribution Stations

These distribution stations can be tailored into many types but we here take such item from the point of view of actual layout as a standard performance for illustration. Fig. 10 – 20 draws the actual 6 - 10 kV single bus bar system lay out with its single line diagram but the double bus bar style has been indicated in Fig. 10 - 21.



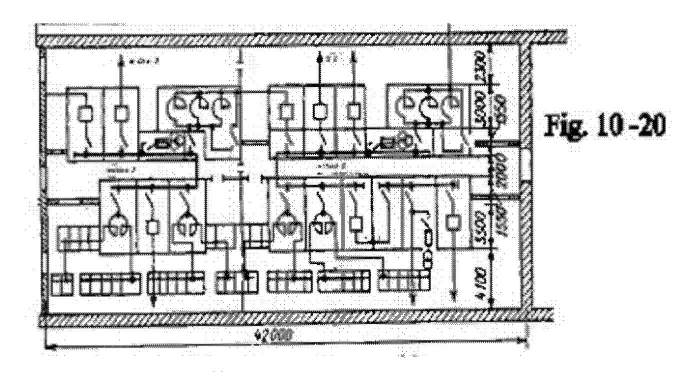


Fig. 10 -20

The most common style of structure for the LV distribution station appears to be the steel frame structure because it has many

advantages as written above. For the level of voltages up to 11 kV, as given in Fig. 10 – 20 for the single BB system, the lay out indicates the secondary cable tunnels as well as the HV wiring. Also, the single line diagram for a station is given in the figure while the reactor limiters are inserted in the single line diagram. Similarly, the double BB system for the same type of stations at 6 – 10 kV level is given as a lay out with the single line diagram in Fig. 10 – 21.

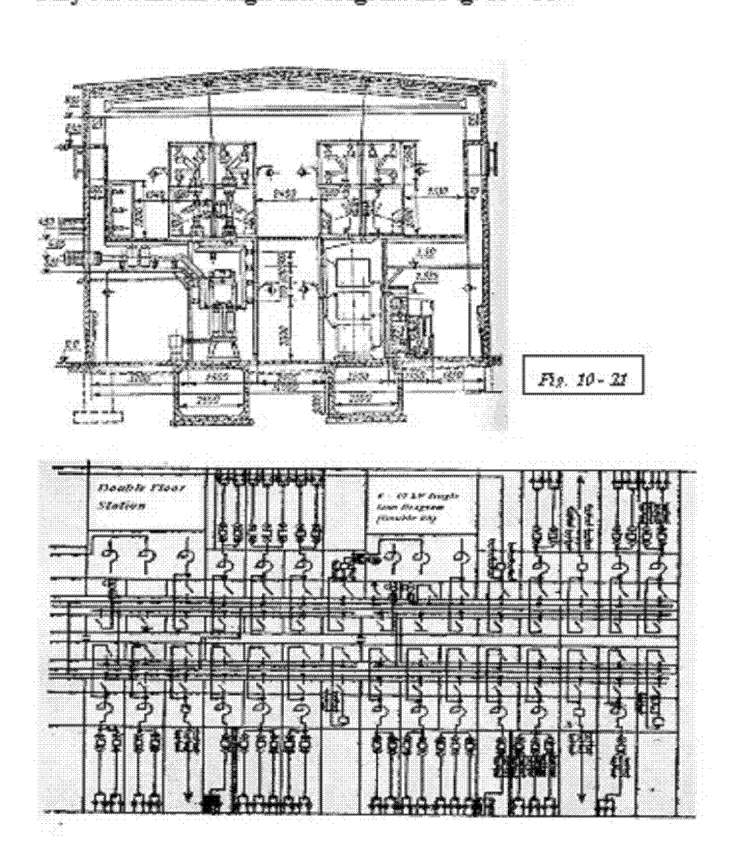


Fig. 10 - 21

In the case of single BB system the allocation of BB is a vertical installation type while it is horizontal with the double BB style.

This is not the rule where both horizontal and vertical are possible for either single or double BB systems. Also, this can be implemented with the triangular shape of BB for the same levels but it is rarely.

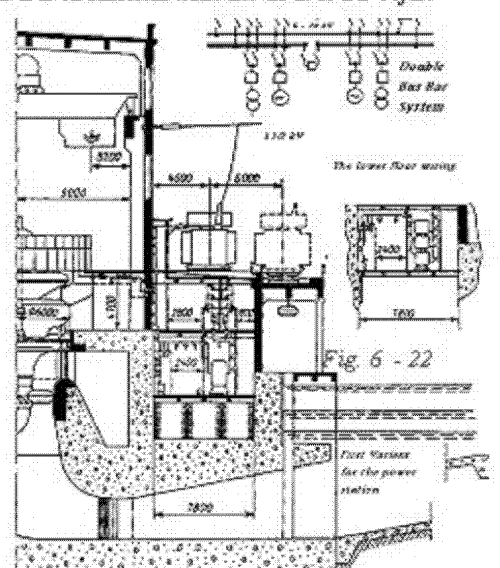


Fig. 6 - 22

Firstly some standard practical applications may be inserted in this explanation here for the purpose of illustration as the different variants for the 6 - 10 kV actual installations as shown in Fig. 10 – 22. The single line diagram has been drawn in the same figure where it can be mentioned that this lay out is given for a power station where the generators are connected within the single line diagram. It has also, a double BB system but here only one of the two Bus Bars is sectionalized.

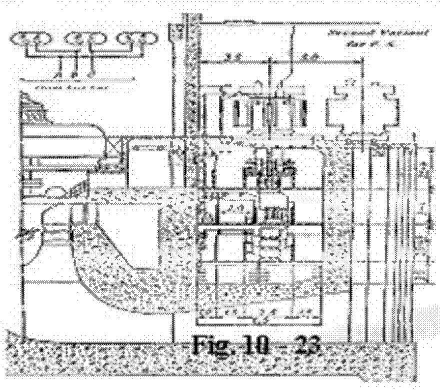
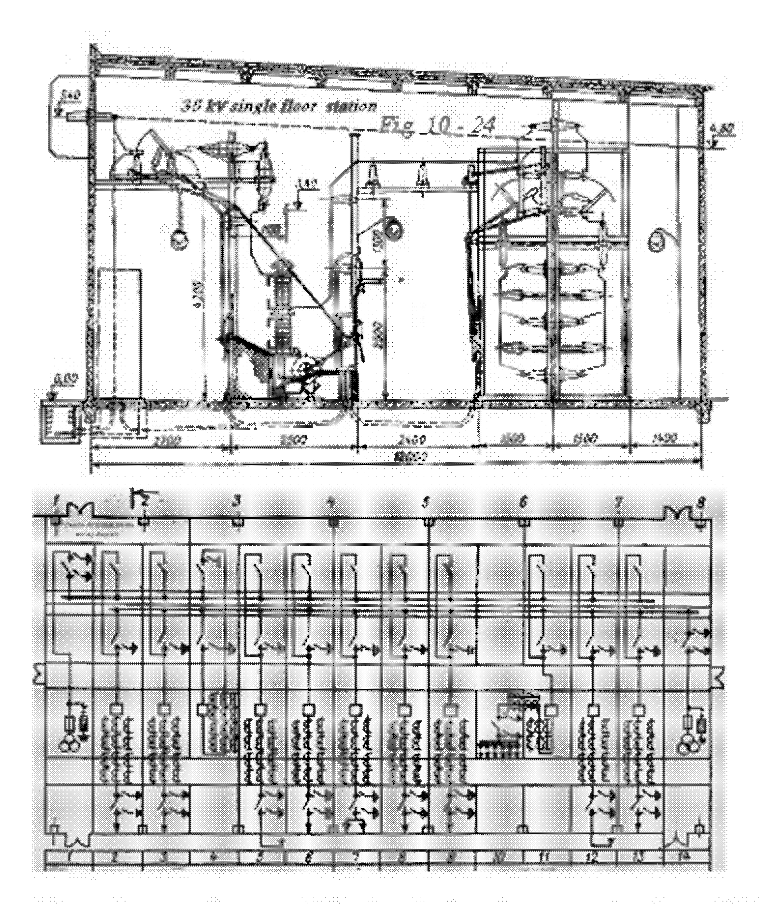


Fig. 10 - 23

The steel structure has been utilized within the hydro power station site. It should be indicated that the 110 kV level will be the outage of the single line diagram while the generation will be at 19 kV.



Otherwise, another practical installation for a station but with another new tendency for the utilization of such locations inside a hydro power station is presented in Fig. 10 - 23.

It is seen that the connection are installed vertically instead of the horizontal shape. It is more suitable in order to utilize the height difference in Dam stations.

On the other side, the next step of voltage of 35 kV may be considered to put a standard practical installation is shown in Fig. 10 -24.

It is a single floor station where it may be in other cases multi floor location for the station. Also, the BB direction is perpendicular to the direction of installation of all part of the station except the bus tie unit. In fig. 10 – 24 thee single line diagram is given because it is the base for the lay out. It simplifies the process of projection for the elements of the circuits in the station.

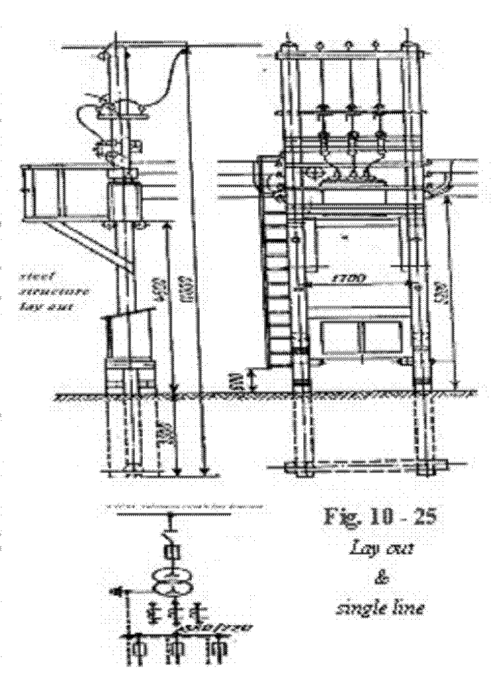
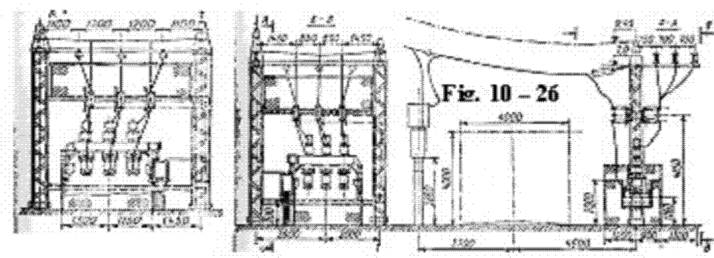
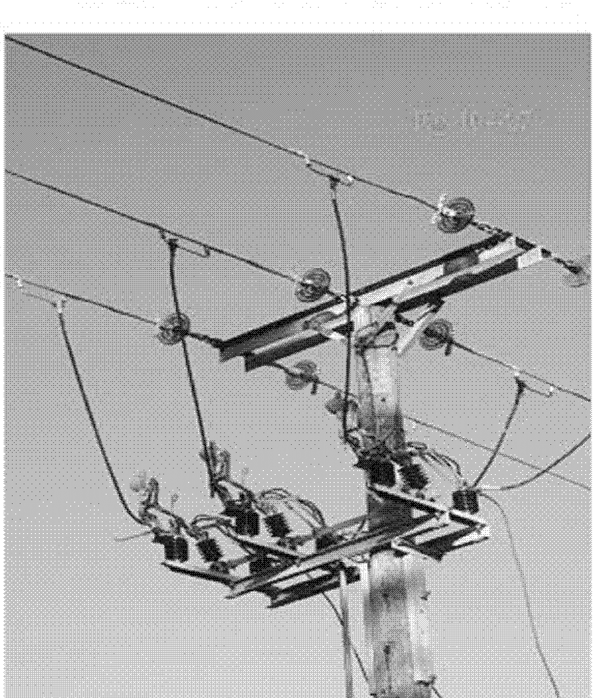


Fig. 10 - 25
Lay out
&
single line

The indoor structures will be the main implementation in such section so that the most of them will be either a steel structure for outdoor or for building indoor style. Fig. 10 – 25 presents the steel structure type for 6 - 10 kV standard while the single line diagram has been illustrated at the bottom of the same figure. Otherwise, Fig. 10 – 26 gives the same layout but for the voltage of 35 kV. In the last case a general steel portal has been used.



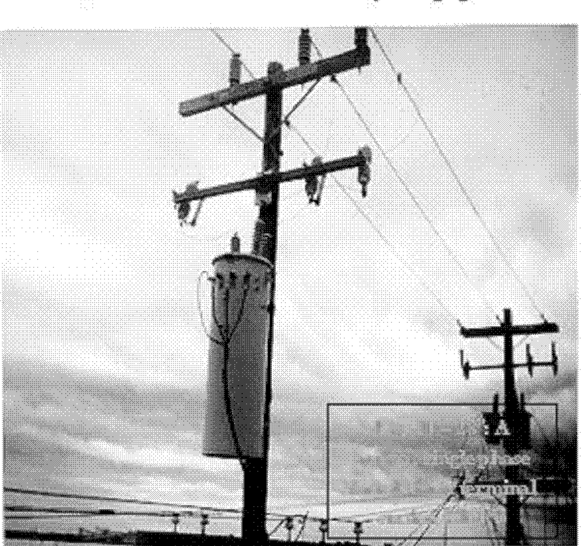


It is the simplest type of structures because it can be implemented in the two axes of Cartesian coordinates of the station (x and y axes). This reduces the total cost of a station.

10 - 3: HANGED STATIONS

Both metal and wood structures are widely used for LV installations because of the low price and suitability for installation in far lands as well as in rural projects. It is easy to apply with minimum defects on lands so that it may the best solution for individual stations or a private supply in desert lands. Therefore, their applications for stations in rural lands as well as in agriculture area can be considered the most economic way so that it may be the style of all distribution stations in such places.

It is more convenient to go through the hanged stations which means that the station totally would be installed on a single structure. Then, an input / output power supply must be at the same place so that it may be a simple connection. This can be achieved if the required power is small. Thus, it can be used for both very low population and the rarely places. The far desert or hill points may be suitable for this implementation. This item can be tailored simply in the next forms for the hanged distribution stations:

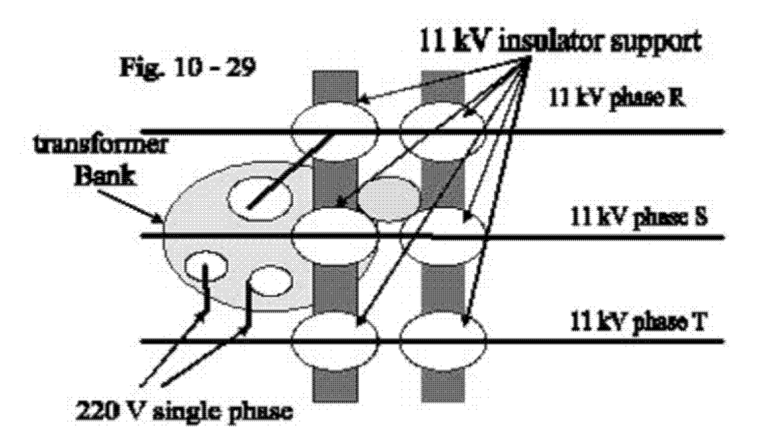


1- On a Transmission Tower

However, we treat the power supply to a small area so that the consumed power may be very low. This needs small power transformer or a simplest form for a substation. So, the supply power may be a part of the running power. This may be easy understand because it is similar to the tapped feeders. Fig. 10 – 27 presents such a case where a transmission line is tapped at a point on the tower to be a supply for terminal consumer.

The picture illustrates that the input switch to a station will be hanged on a tower as shown but the station must have another metal structure to support a transformer with its circuit breaker. It is a practical solution to save land and money. It is remarkable to find out that the transmission tower itself has been utilized to save a tower. It is a tapped tower style similar to the tapped feeders.

This procedure may be fulfilled by a single tower on a transmission line where the transmission line 11 kV is tapped to a single phase transformer. This case is given in Fig. 10 – 28 where all components of the station are seen on the tower.



Then, the output of this transformer at 220 V can distribute the power in a local area which cover the power of this single phase transformer. It is a simple method for a tapped transmission line where each tap takes the power from a phase in sequence.

This means that the tapping will be from phases R , S and T , respectively. The lay out of this station will be as shown in Fig. 10 – 29.

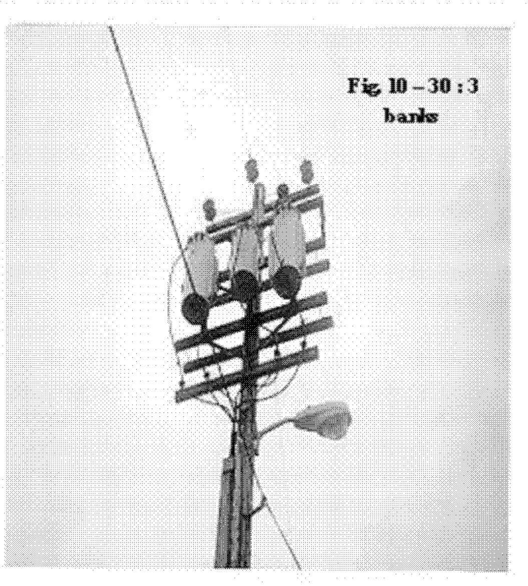
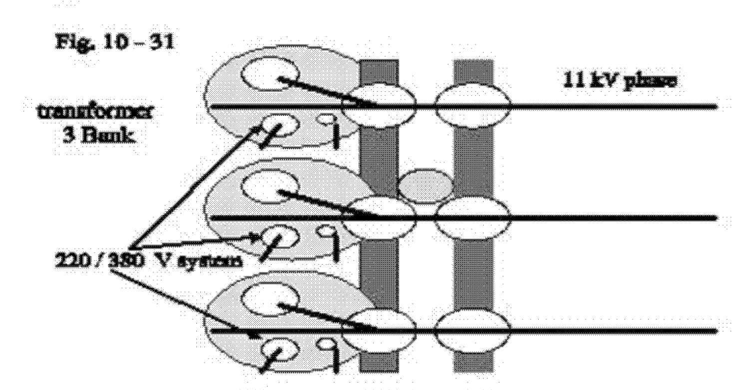


Fig. 10 – 30 : 3 banks

Fig. 10 – 31



This station may be entitled as the R station because it takes the supply from the phase R with the earth point. It is also, seen from Fig. 10 – 28 that the next tower have the S station and the third T station later.
Another concept for such station is used as it is seen in Fig. 10 – 30 where three similar banks are installed on the same tower. They form a complete three phase transformer. They also supply the zone when the power required in such zone is large so that a three phase system will be necessary. However this 3 individual banks give more reliable system and it saves the connections on the other two towers but it is economic if this tower is the center of local loads in the zone. The lay out of this station is given in

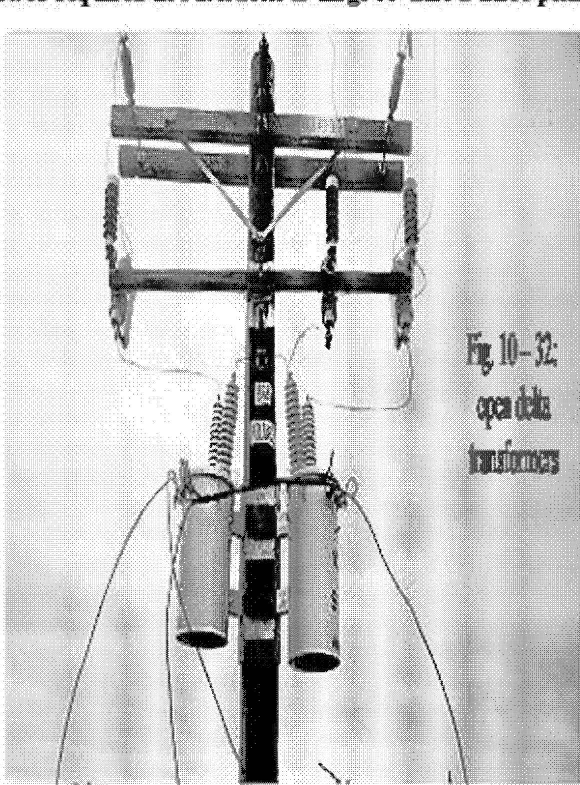


Fig. 10 – 32: open delta transformers

Fig. 10 – 31 which shows details of the wiring diagram on the plan. The plan did not project the lamp on the tower because the lay out is a projection for the connection diagram of the station only.

2- On a Special Tower

Otherwise, the terminal systems may be installed in different ways to reply the requirement of loads at various points on the network. This may be done for a certain operating condition according to the characteristics of loads. On the other hand, this concept of individual banks transformers may lead to a special connection for the transformer banks in order to utilize the transformer grouping angle for a new voltage difference. This idea may be clear with the transformer station on a tower of Fig. 10 – 32 where two individual single phase transformer banks are installed on the tower. They are connected as open delta to reply the requirements of the supply. The open delta station is installed on a special tower as shown from the figure. It is another shape for the stations on towers.

10 – 4: CIRCUIT BREAKER UTILIZATION

The isolating link can isolate a part of the network away from an another although it cannot break the circuit current. It is a tool for isolation between the life part from earthed parts, or from the other life parts, or from the non- life non-earthed sections inside the station. It is an important tool in the sequence process of switching in the station either generating or transformer station. This device is a safe one for other equipment such as circuit breaker or power transformers or measuring potential and current transformers. It is also, a main device to isolate the bus bar from cells. Its importance appears with the engineering switching processes as well as during the testing conditions and for maintenance.

The circuit breaker in a network plays a main role to keep it reliable as the interruption of the power supply at the user end is forbidden. The circuit breaker opens a circuit as ell as closes it. It has an arcing chamber in order that the sparks can be generated and then distinguished. It helps the circuit to be out of service safely. The circuit breaker costs high relative to isolating links although its use is

a basic need.

Therefore, all projects or proposals for the design of electric stations in networks try to minimize the quantity of circuit breakers in the scheme (single line diagram) with the raising in voltage. Contrary, with UHV sometimes more than a single circuit breaker base may be required to insure the reliability of operation. Thus, different connections through the single line diagrams may be tailored in the following sections.

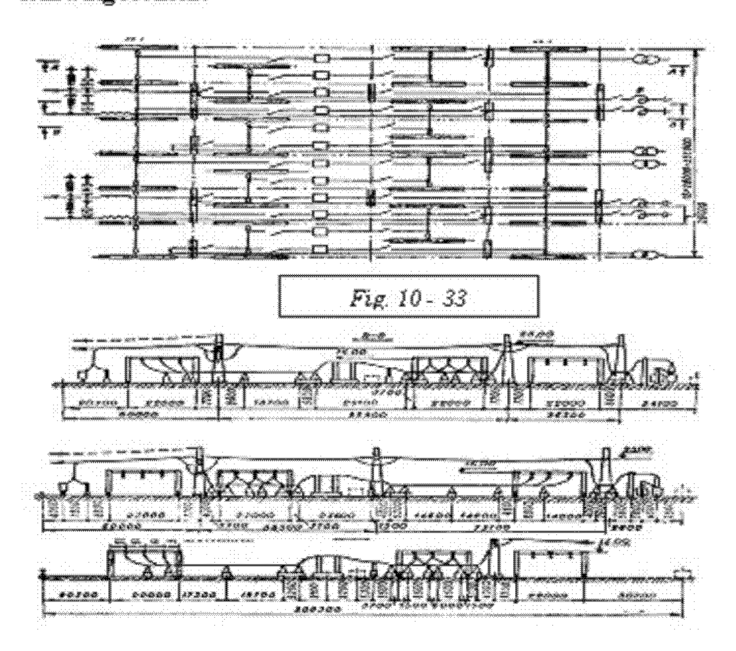


Fig. 10 - 33

I- Single Circuit Breaker Connection

This technique is the most economic solution in the design due to the use of only one circuit breaker for the device or the cell as it is shown in Fig. 10 – 33 for the 500kV level. It should be seen that Fig. 10 - 33 is the layout concept for the item from different points but the terminal connection of the winding of the transformer to the wiring

in the yard should take the complete care for area of connection as well as the bolting efficiency. This is considered in the lay out as this metal plate connector makes the connection very well.

II - Double Breakers Function

For more reliable schemes a second circuit breaker is inserted to be double function circuit breakers as given in Fig. 10 - 34 for the level of 500 kV with its single line diagram as indicated in the figure. For higher voltages it will be similar as in Fig. 10 – 34 for the 750 kV station. Only the dimensions of 750 kV station may be increased greatly.

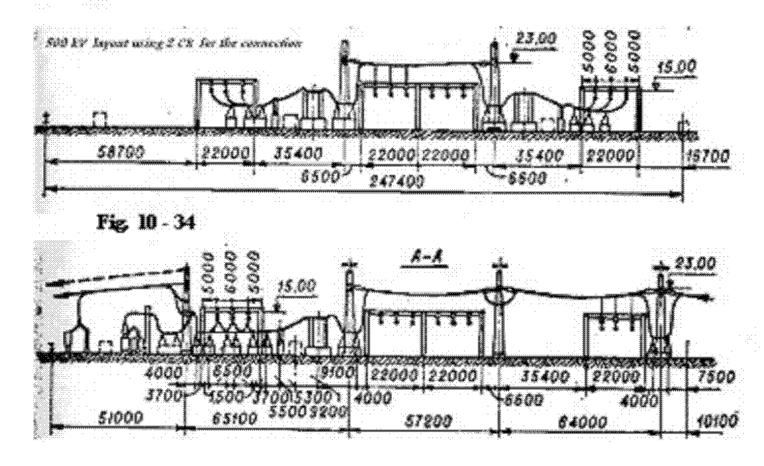


Fig. 10 - 34

III - Triple Breakers Diagrams

For the 500 kV above diagrams it is needed to raise the reliability of operation of a power system due to the heavy transmitted power through the cells. The triple circuit breaker insertion in a circuit presents the use of three circuit breakers for the connection between a transformer cell and a transmission line cell.

This clarifies the benefits from such schemes. The single line diagram must explain the connection well. Its practical wiring controls the lay out performance either connection or crossing and sometimes the

direction of the pole terminals on the projection relative to the direction of the cell. The electric connection is simple but the problem will be appeared with respect to the real application of the point of connection.

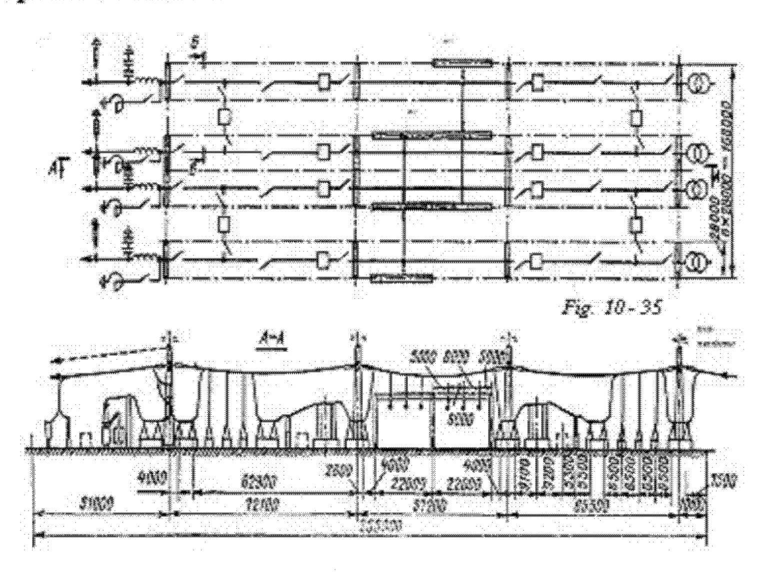


Fig. 10 - 35

IV- Four Circuit Breakers

The use of three circuit breaker is a useful tendency so that the increase of one circuit breaker with them leads to a more reliable than the triple implementation. The design of this condition is presented in Fig. 10 - 35 for the 500 kV level where both elevation as well as the plan of the wiring in the station would be a complete projection for the wiring inside.

V- Transfer Bus Dependence

The transfer bus or the standby (Reserve Bus) can be implemented typically as given in Fig. 10 - 36 for the 330 kV as a single line diagram while for 220 kV it may be shown in Fig 10 - 37. It is used sometimes as a connection bus where a synchronizing device is

located in order to check the ability for coupling.

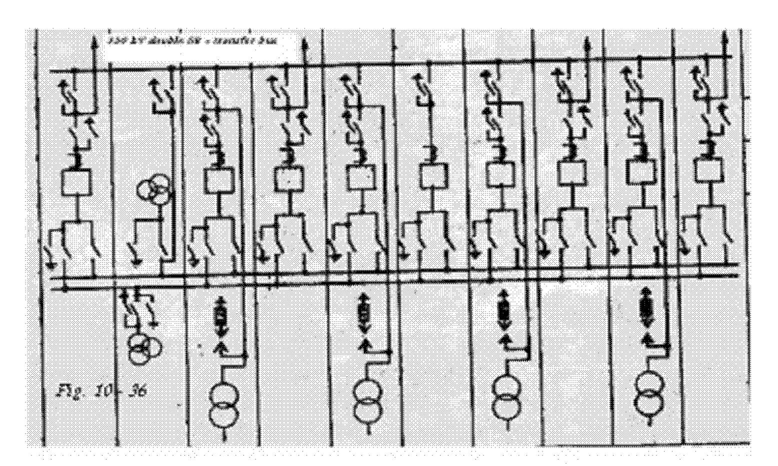


Fig. 10 - 36

It should be point to the similar strategy of the cell arrangement for both EHV or EV or LV and even for the distribution voltage as the same shape is watched. It is seen from Fig. 10 – 36 that the arresters are a major apparatus for the winding of transformers. Also, it is important for the BB so that any BB must be connected to arresters because it is a node in the connection diagram. Consequently, it may protect the point (node) and all windings connected to it. Arresters are a major elements at:

a) Ends of a line
b) Terminals of transformer windings
c) Terminals of generator windings
d) BB of a station

On the other hand, the steel structure station is shown in Fig. 10 – 37 for a 220 kV where it is similar completely to that of 35 kV but the dimensions are larger. The steel or metal structure may be the most economic as indicated before.

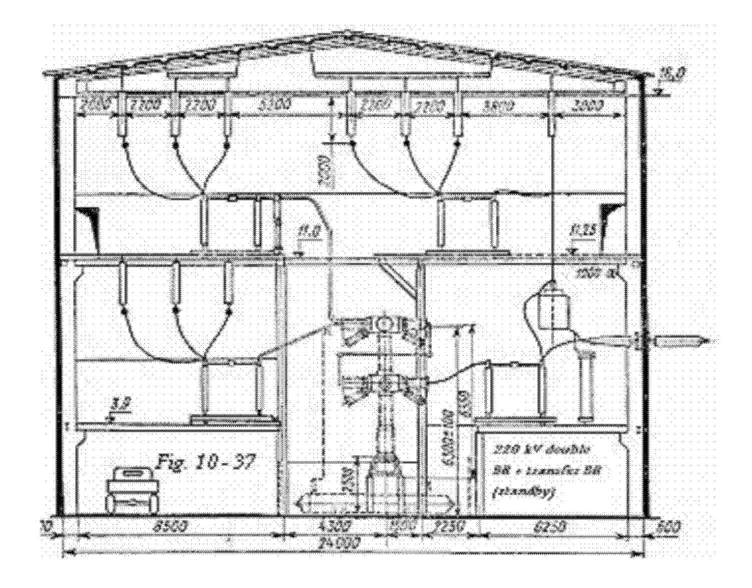


Fig. 10 - 37

It is seen that the traffic ways must be considered even with metal structure stations where all hanging tools must be a tension style hang. Then, with the self work either during installation or after starting the operation if a maintenance needed. This is important for maintenance works. It is shown in Fig. 10 – 37 that the Bus Bars of the double BB system are horizontals.

Finally, the lay out of a station may be considered as a vital part of the design. It must be the actual practical wiring for the single line diagram so that the single line diagram may be presented with its lay out together. This takes an important meaning because the variety of single diagrams and their layouts may be a large number. The selected final one or exactly final groups of variety should be presented for the purpose of differentiation between all proposals.

Chapter XI

MATHEMATICAL PROCEDURE

It is known that the process of design for a station depends on the factors affecting the situation, environment, the condition of operation, the geographic location as well as financing. So, the procedure of calculations of different items inside a station must be explained in order to make the process very easy. All steps of calculations are simple although it may be done on the basis of the standard tabulation. On the other hand, the contents of a station with its various shapes and types have been illustrated and consequently the computation of all components individually in the station may be the aim to reach. Each calculated parameter or part in station would be checked again with the next collection with other parted related to. The overall understanding for the subject is the best way to get a best design.

Otherwise, the mechanism of evaluation appears to be a complex one so that it can be implemented through the superposition technology. Therefore, the element will be the item of the work but with its parameters included for the design. Such concept would be tailored into the following categories. This includes the elements inside each cell in the layout, the electrical parts inside, the mechanical sections, the chemical components and the civil operations included in the station parts.

11 – 1: BUS BAR GEOMETRY

Bus bar geometry means all dimensions of a bus bar where the diameter as well as the type and shape of its conductors in addition to their spacing inside a station are the major items of the design process. The calculation principle depends on heat accumulation due power loss as well as on the current density carrying conductors. Also, the geometry of the land as seen before can be a factor for the choice of the type of conductors. This required conductor may be analyzed for the maximum allowable value of current passing through any section of the BB. So, the current effect would be

inserted in the process besides some different factors as given next. On the other hand, the mechanical stress has a vital roll in the conductor selection in spite of the system of tabulation for such stations. Different tapping must be considered so that the mechanical forces on the conductors become high. All tapped points would be highly pressed as well as a standardization style may a good engineering tendency for this item.

1- Current Density Dependency

Current density appears as a major target for the calculations of diameter or cross section of a conductor in spite of the small variants for the conductor materials and the type available. The current density would be taken the minimum value because the current is passing always without any stop. This is a fact the must be considered as the base for the current density choice. Thus, the diameter of the BB conductor will be calculated as:

BB cross sectional area = maximum nominal current / minimum current density (11-1)

This formula must be modified according to the design factor and then, the value could be moved to the next higher value of the standard conductors.

Accordingly, a table style, for the evaluated BB conductors at all levels of voltage, can be created for use, in the next steps of the calculations, in the form:

Table 11 - 1: The BB diameters

Voltage	Current	Theoretically Calculated	Designed (Standard diameter)	Required length
HV				
MV				
LV				

During the check for the deduced diameter from the design calculation we may face a problem when the diameter may be impracticable. This means that the diameter is larger than the maximum standard conductors so that a Bundling base will be considered.

2- Voltage Stress

The voltage level will take a main role in the determination of the Spacing between conductors of BB and their Height in order to get the final geometry of BB. The conductor allocation will be horizontal for out door installations will it may be placed in different shapes as given before. This case may be expanded for the indoor stations due to the different types of geometry possible for the BB. All cases must be taken into account when the designer prepares his project for a station.

3- Corona Check

It is known that corona is a form of the self-sustained discharge (with a radius r_q), typical for the sharply non-uniform fields. It is important to indicate that volume charge of the separate phases mutually interacts with each other. As the polarity is changed per a cycle for the AC circuits, the charges on a conductor will be attracted in the second half-period. For maximum spacing of the volume charges, the intensity of the field on the surface of a conductor (radius = r_o) will be considered as a constant (E_r) value during the half period. Its value may be equated to the critical value(E_c) as:

$$E_r = \text{constant}\ ,\ E = E_c \times r_q \ / \ r \qquad (11\text{-}2)$$

Also, the maximum voltage for the greatest volume discharge from the axis of conductor with corona can be theoretically found by the approximate formula:

$$V_{max}{}^2 = K\, T\, E_c \;\; r_o \qquad (11\text{-}3)$$

For example using this equation, if we have that:

$r_o = 1.25$ *cm*, $K = 1.8$ *(cm/s) / (V/cm)*, $E_c = 36$ *kV/cm* & 50 *Hz*,

The greatest separation for corona will be calculated as 40 cm. This value is less than the actual spacing between conductors.
Corona causes a loss, which is determined as the charges transfer from the coronized conductor to the other. It is a leakage current for the DC circuits while it differs for the AC networks. The corona power loss (P) may be experimentally deduced by the equation:

$$P = [241(f + 25)/\delta](r_o/S)^{1/2}(V_{ph} - V_o)^2 \times 10^{-5} \text{ kW/km /phase} \quad (11\text{-}4)$$

Where
δ Relative air density
r_o Conductor radius (cm)
S Mean geometrical distance between conductors (cm)
f Frequency (Hz)
V_{ph} RMS value of the phase voltage (kV)
V_o Calculated voltage close to the critical corona voltage.

On the other hand, sometimes in some cases a corona presence may be needed in spite of its power loss in the circuit. Then, the value of the critical corona voltage follows the mathematical formula:

$$V_o = 21.2 \ \delta \log (S / r_o) \, m_1 \, m_2 \quad (11\text{-}5)$$

Also, the coefficients m_1 and m_2 are the smoothness and weather coefficients, respectively. In order to reduce the corona loss at AC networks, maximizing the radius of the conductors is a target. The absence of corona loss in fair weather can be evaluated by getting the phase voltage to be less than critical close voltage V_o.
This item will change the above results to reduce the loss in the BB, especially, with the continuous loading during 24 H a day.

4- Final Standard Dimension

After the actual standard conductors suitable for the design, the choice of the final standard dimension of BB has been found. This finishes the electric part of BB design, and consequentially, transfers our job to the mechanical design.

The mechanical design of a bus bar mainly depends on the maximum strength affecting the holding points at the ends of the BB conductors (Fig. 11 - 1). It is similar to the mechanical design of a transmission line conductors.

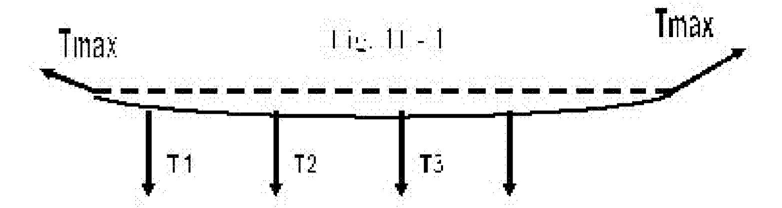


Fig. 11 - 1

11 - 2: CELL DIMENSION

Figure shows some distributed forces on the conductors of a BB where the connections of cells to the BB must be held to fix the cell contents to BB. The calculation may be done for equal forces at these points. Such determination can develop the needed type of string at both ends. Due to the high strength in large HV stations, the double string insulator type will be better than the single. The practice indicates the style of double string is the most required one.

Table 11 - 2: The individual elements for a cell

Element	Calculated	Designed	Standard value	Place	Required quantity
Insulator Clamp Portal					
Support					
Others					

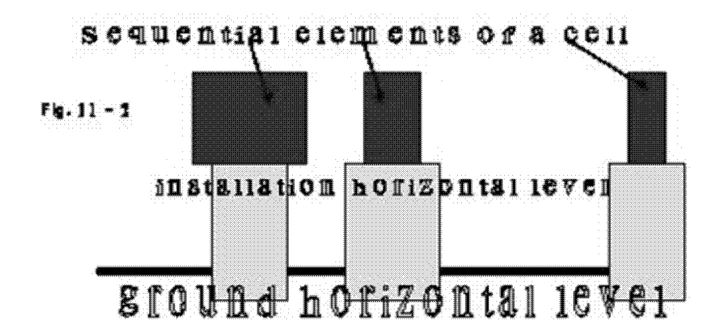
For indoor stations the strength will be supported on a point instead the tension type of Fig. 11 - 1. In this case the BB may be a pipe or bar so that it must be fixed at only one end. The other end should be relaxed fixing to permit the expansion process with heat rise due to current passing. The portal design can be achieved on the mechanical design of BB while sectionalisation can develop the performance of such design. This means that the maximum strength may be reduced when decreasing the distance between the portals at both ends. Thus, a design will be completed.
The above calculations must be translated into tables to find both the type and the quantity required for the installation as given for example in Table 11 - 2. The summation quantity for all cells may be found from the individual table as Table 11 - 2 to be expressed as in Table 11 - 3.

Table 11 - 3: The Final Requirements

element	Standard value	Required quantity	price	cost
Insulator support				
PT CB Alternator				
Isolating link				
Insulating string Conductor Others				

Another table could be done to resume the cost of transportation, customs, installation, testing, maintenance, training and others to get the total final cost for the station.
In order to get the above total requirements, the cell dimension must be determined as done for the BB above. Always, the calculations of conductors of a cell depend on that of the BB itself to unify the conductor diameter. Spacing of a cell is the same as for the BB to prevent the corona loss.

The contents of a cell may be tabulated and another table to collect all cells in each equal voltage level. Sequentially, a sum table for all BB sections and all BB at all voltage levels can be generated before the final table for the cost calculations. All types of cells may be inserted as:



a) Single horizontal Level Cell

Here the term horizontal indicates that the installation of all elements of the cell is based on a horizontal plane as shown in Fig. 11 -2.This also related with the subject of cost due to the introduced plus elements through out the different components because of the symmetrical allocation of cells or the supporting feature required.
This horizontal shape of installation is the normal used characteristic over all the world and it is suitable for all countries inside cities or out side. This is applied for either power stations or substations and also, the distribution stations. The given above tables are taken for this type of installation so that it is convenient to treat the design feature by the designers.

b) Multi level Cell

It is important to see that sometimes we need to supply a place on a hill or on mountain so that the horizontal ground cannot be found. Then, the replacement of it in a new style for the installation of a

station will be a major requirement. Thus, the non horizontal shape of installation will be appeared leading to the different types of this installation.

Figure 11 - 3 shows an example for a double level cell installation while the connection between the elements will be subjected to a certain fixation to eliminate the conductors of high voltage from the ground. This is ruled by the feature of spacing for the normal HV wires away from the earthed points or metals near the HV wire. This will raise the number of supports to fix the wires as it is shown in Fig. 11 -4.

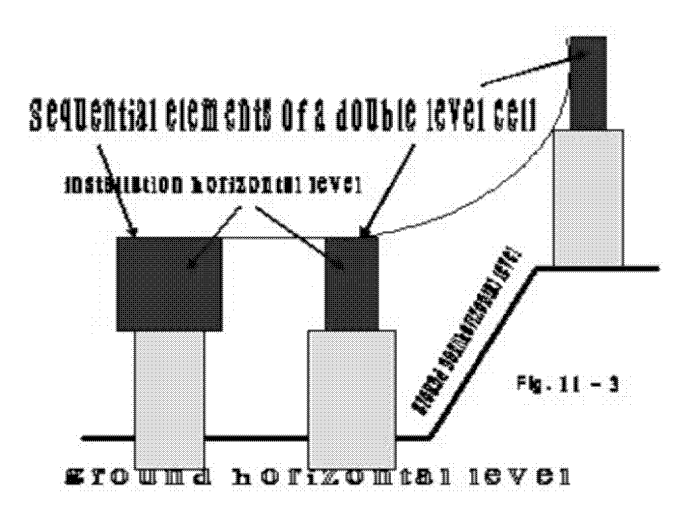


Fig. 11 - 3

The style of double level ground may be developed into a multi level cell is given in Fig. 11 -4. This may be more clear with the shown wire hanging between different elements of the cell.

In other words, different styles of a cell according to the installation of the joint point between IL and CB in double BB systems may be taken into account as:

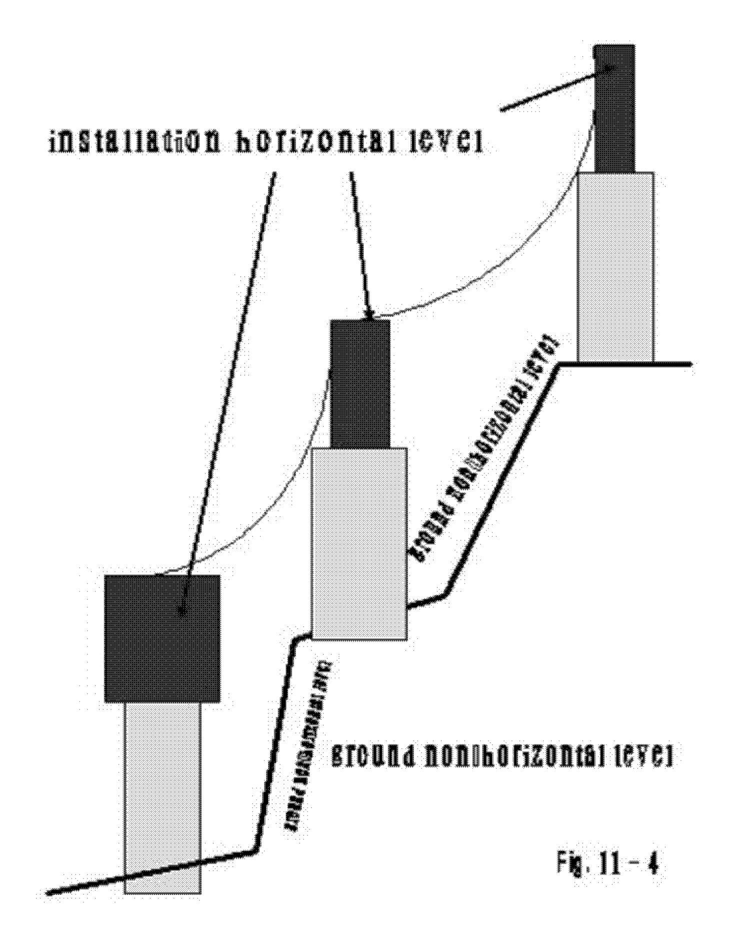


Fig. 11 - 4

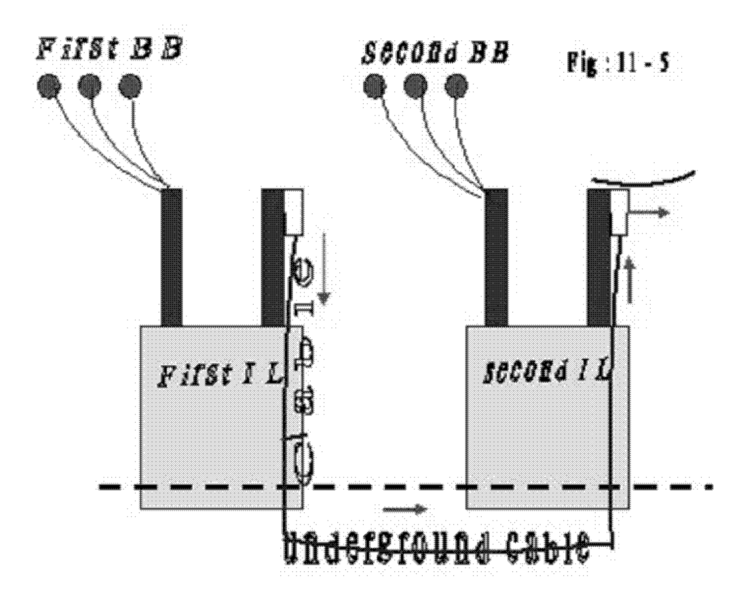
a) Underground Style

Using this style the connections between I. L in a cell will be implemented through underground cables. This minimizes the

distance between them and so, the land required for other types of connections. It also, will be reflected on the cost of land as well as the conductors but the cables will be more expensive. This is the idea from the economic point of view unless the reflected wave process would be considered. The cable ends should be used at terminals of the cable as shown in Fig. 11 . 5 where the cable must connect both common joint of the two isolating link. This joint will be connected to the CB terminal.

b) Longitudinal Allocation

In this case the two isolating links for the double BB connection in a cell could be installed in series inside the cell and consequently, the land needed for a cell will be more. The length of a cell would be increased, getting more land and conductors as well as portals, so that the cost may be increased.



c) Parallel Allocation

This condition of allocation can modify the above case to minimum length of the cell but it will consume a width more than that of the longitudinal one. On the other hand this problem may be solve by the utilization of the spaced area inside the cell, depending on the addition of portals in the site. Thus, the cost will become less than both above cases.

d) Vertical Concept

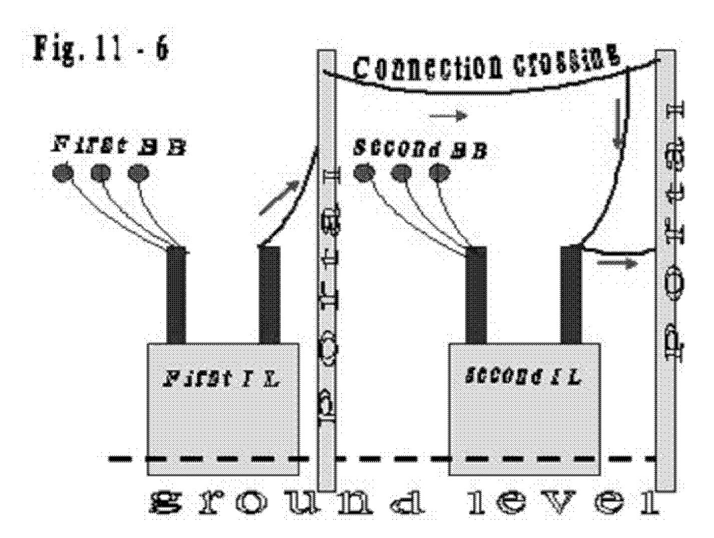


Fig. 11 - 6

The vertical direction in the outdoor stations will be more effective because the air above is free. The portal installation will minimize

the condition by combining both longitudinal and parallel cases together to give the optimal solution in the subject concerned. The corresponding illustration can be seen in Fig. 11 - 6 where this concept is suitable for the indoor stations. The two wires connect the CB terminal to the second terminal of the isolating links.
Then, the Overall Dimensions would be evaluated for both Minimum and Maximum Lengths leading to the Final Dimension for Cells.

e) Area Utilization

As it is explained for the aim of minimizing the cost we need to consider all less dimensions. It may be clear as the combination between Horizontal & Vertical installations for the isolating switches. The represents money going to raise the cost of the station under design because the land price is always going up with its rise rate. This takes as an important factor in developing countries due to the increase in the population in high rates. On the other hand, the stations now are installed inside cities not outside where the land price is great.

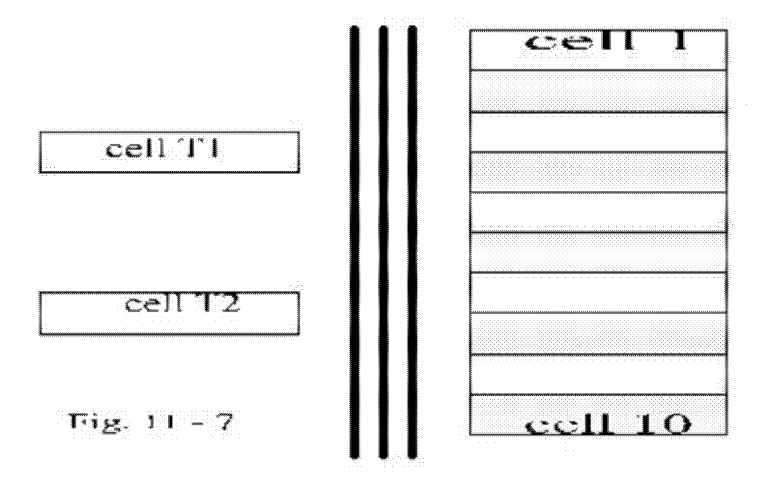


Fig. 11 - 7

Also, the vital aim can be achieved by the replacement of the Direct

Connection for the transformer cell inside a S. S. to become with a Reverse Return Style. The goal we can reach will reduce the area to its calculated half value. Figure 11 . 7 gives the area required for example 10 cells and 2 transformers. This means that the used area for such number of cells may be generally formulated as:

First total area (fig. 11-7) = 2 × No. of other cells × cell area (11 - 6)

In this equation the number of transformers is absent due to the larger number of other cells as in the real situations and applications. an see for a 10 cells and 2 transformers cells the area required will be 10 cells from both sides of the BB, i. e. 20 cells area. The required area for the station will be 20 cells area in spit of the number of transformers in it. This is a real condition due to the normal small number of transformers in a station relative to the other cell. Then, we will need a place for 20 cells (10/each side).

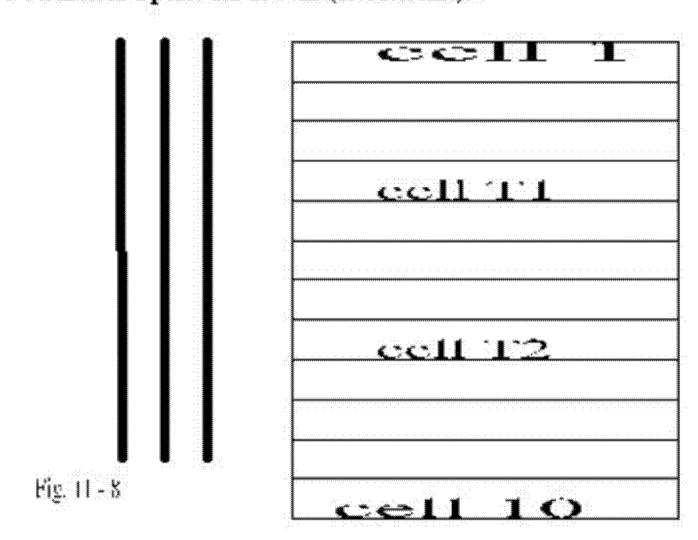


Fig. 11 - 8

The direct connection means that the layout of transformers cells to the left of the BB while the other cells must be to the right side only. This means that the useless area will be calculated as the free land inside a station. So, the cost of land will become more than that needed actual where this excess in the land inside a cell may be called as a lost area. This is not preferable so that an economic engineering solution must be created in order to minimize the lost area. Also, many styles of connections or even allocation positions for an element inside a cell may lead to a minimum area use and sometimes without lost area.
On the other hand, if we use the concept of reverse direction for the connection of a transformer cell (Fig. 11 - 8), we can reach to a new area less than the old one according to the formula:

New area with reverse connection *(Fig. 11-8)* **= (No. of transformer cells + No. of other cells)× cell area** (11 - 7)

Thus, only 12 cells will be equivalent to the same case in the station and the number of total cells in the station will be only 12 and it represents the required area in the given example.
Consequentially, in this condition the saved area will be based and it can be calculated according to the simple formula:

Saved area = Old area – new area (11 - 8)

In order to get the real effect for the new concept the saving ratio in the utilized area can clarify the aim according to :

Saved area ratio=saved area / old area = (½) (1- No. of Transformers/ ***No. of other cells*****)** (11 - 9)

Then, with the technique of reverse type connections for the transformer cells as drawn in Fig. 11 - 8 we can find that the required area will be only 12 cells. This proves that the saved area is 8 cells. Then, a classification for the area can be taken in three categories:

1- Symmetrical Area

This means that all cells must be symmetrical in size, distribution of similar elements and the center line for each item inside the station relative to all cells in.

2- Technical Area

This term means the area required for cells from the point of view of engineering as it has been illustrated in Fig. 11 - 7 and Fig. 11 - 8. It is calculated depending on the electric performance for each element.

3- Working Area

It is defined as the required area for different works such as maintenance or installation and operation or testing.
The above analysis for the area of a station could be formulated as:

$$\text{Station area} = \text{Technical area} + \text{Working area} \qquad (11\text{-}10)$$

11 – 3: IMPORTANT FEATURES

All calculations have been international done, and then, results were gathered in the shape of tables. These tables means the standard dimensions for each level of voltage or current according to the concept of application. So, the Table 11 - 4 presents the standard dimensions for the cells for either outdoor or indoor stations where the dimensions are given in meters. Also, the panel form of cells in constructed stations must be configured according to the same standard and values in spite of the level of the rated nominal power (either small or large scale).

Table 11 - 4: Standard Dimensions For Cells, m

(kV)	6 – 10	35	110	220	330	500	750
Indoor Spacing	.5-.6	.6-.8	1.4-1.7				
Indoor Cell Width	2.2	3	6				
Outdoor Cell Width				14	16	18	21
Outdoor BB Spacing			3	4	5	6	10
Outdoor BB Height			7.5	10	11	14	26

There are different special cases where such dimensions may be varied for safety conditions during the design process as seen in Table 11 - 5. This means that more spacing can be implemented while the opposite is forbidden.

Table 11 - 5: Cell Dimensions, (m)

Voltage (kV)	35	110	150	220	330	500	750
width	6	8	11	15	22	30	41
length	40	60	80	90	120	160	280

Similarly, the standard dimensions for the stations such as substations in the indoor style are indicated in Table 11 - 6.
The major parameters for the indoor type of Distribution Stations (Main – Secondary – Terminal) can be delivered as shown in Table 11 - 7 where all dimensions for the data listed in this Table are given in cm.

Table: 11 - 6: Standard Dimensions of Indoor Sub Stations, m

Voltage (kV)	Transformer rate MVA	Out going lines	*Station Dimension, m. m*	Weight without *transformers*
110/35/6-11	1 x (5.6-20)	4x(6-11) + 2x35	30x35	35
110/35/6-11	2 x (5.6-20)	8x(6-11) + 4x35	34x57	35
110/6-11	1x(5.6-15)	4x(6-11)	20x27.5	18
110/6-11	2x(5.6-15)	8x(6-11)	27x35	37
35/6-11	1x(3.2-15)	4x(6-11)	12x14	15-20
35/6-11	1x(0,56-3.2)	4x(6-11)	12x14	10
35/6-11	2x(0,56-3.2)	8x(6-11)	14x20	14

Table 11 - 7: Indoor Stations Parameters, (cm)

Voltage (kV)	3	6	10	20	35	110	150	220
Calculated minimum spacing between phases	7	10	13	20	32	100	140	200
Calculated minimum distance between a phase and ground	6.5	9	12	18	29	90	130	180
Practical (standard) spacing	20-30	25-50	30-70	50-70	50-70	125-160	200	300
Minimum distance from conductors to the wall	9.5	12	15	21	32	93	133	183
Minimum distance to adjacent circuits	16.5	19	22	28	39	100	140	190
Height of non-energized parts to adjacent circuit	200	200	200	220	220	290	330	390
Height of non-energized parts to ground	250	250	250	270	270	340	370	420
Minimum Distance of entrance to ground	450	450	450	475	475	550	600	650

Table 11 - 8: Outdoor Stations Parameters, (cm)

Voltage (kV)	? 10	20	35	110	150	220	330	500
Calculated minimum spacing between phases	22	33	44	100	140	200	280	420
Calculated minimum distance between a phase and ground	20	30	40	90	130	180	250	375
Practical (standard) spacing (Worst conditions)	40		100	140-190	200 - 300	250 - 400		
Practical (standard) spacing (natural conditions)	40 - 60		120 - 200	200 - 300	350 - 425	350 - 500	450 - 600	600 - 700
Minimum distance from conductors to the wall	95	105	115	165	205	255	325	450
Minimum distance under conductors to transported objects	95	105	115	165	205	255	325	450
Minimum distance from energized conductors to the isolated parts	95	105	115	165	205	255	325	450
Minimum height to adjacent circuits (Above or Under)	95	105	115	165	205	300	400	500
Entrance to ground with sever conductors swing	290	300	310	360	400	450	520	465
Distance between conductors of different circuits or to Buildings or connections	220	230	240	290	330	380	450	575

Also, for the outdoor stations the above given parameters may be tailored as listed in Table 11 - 8 where the dimensions are pointed in cm units. The measuring instruments have been collected for the design purpose to facilitate the mission of designers as we can see in Table 11 - 9 the global dimensions for the installation of measuring instruments begging with voltages 10 kV up to 500 kV.

Table 11 - 9 : Standard Dimensions For Measuring Instruments, m

(kV)	10	35	110	220	330	500
CT Diameter	.2-.35	.3		1.2	.1	
CT Height	.412.9	1.1		3.6-5.3	4.9	
Base Dimension	.25-.4			1.3x1.4	1.2x1	
PT Diameter	.1	.15	.4	.5	.5	.6
PT Height	2.3	2.5	3.3	3.8	5.3	7
PT Ring Diameter				2.2	2.4	2.6
3 Pole PT Tank Height	3.4	3.5				
Base Dimension			1.2x1.2	1.3x1.3	1.4x1.4	1.9x1.8

It would be mentioned that the 3 pole PT can be installed only for low voltage as it is seen from Table 11 - 9.

11 - 4: AUXILIARIES

In a Power Station there are more loads than that for a substation because of the pert of generation (electric or mechanical part of the station). It reflects a new added loads in the single line diagram. Such loads in power stations contain:

1- Pumping

There are many types of loads of pumping which is always necessary for either power or sub stations. In the power stations the pumping branches would be greater since a fuel and its requirements of devices will be added. Then, some of these loads may be indicated in the following paragraphs.

a) Water pumping

There are two types of water pumping according to application as:
For transformer cooling if the power is high.

For water in boilers to generate the steam needed for turning the turbines in thermal power stations.

b) Fuel pumping

It is important to transmit the fuel from the storing place to the boilers in stations so that a pump could be a good tool. The rating of pumps must be large and consequentially a higher voltage would be the solution at the levels of 6.6 kV or more.

c) Oil Pumping

This item appears with the large capacity power transformers if the transformer oil is used. These pumps circulates the oil inside the transformer tank in order to increase the efficiency of cooling for the winding of the transformers.

2- Lights

Lights in a station should be tailored into two types:

a) Ordinary Type

This type of light is the normal known one which is applied for steady operation conditions. It may contain the lights inside and out side in the outdoor or the indoor cells or the control room and others. The supply is AC source and the distribution must cover all places either important or not. The main places may be the control room and where measuring by hour is taken.

b) Emergency Light

This type will be very important for the station at faulty conditions so that it must be supplied from a DC supply. The capacity of emergency light must be 10 % of the normal AC light at the places where the work will be needed if a fault occurs. All these items should be introduced in the cost processing in the design computations. Lamps must be distributed in battery and control rooms as well as in other important places such as compressors, .. etc. The final results of calculations would be tabulated as explained above.

3- Rectifiers

The DC station inside the electric station is a vital supply because it covers the tripping process either a limited or an overall tripping for all components of the station. This means that this station must and must cover the faulty tripping 100 % quality at the any bad condition. So, a battery station is built but it is individually not enough. Then, another back up supply should be introduced such as AC / DC rectification style. Thus, the rectifier station will be a link between both AC and DC batteries. It may be used in the normal conditions to supply the protective devices and systems through the rectifier not the batteries. The saving for the batteries will be achieved while this rectifies will charge the batteries continuously as a trickle charger. When the AC supply cut off, the DC supply will take the responsibility to supply the tripping circuits. The importance of DC leads us to put a third supply as the AC motor / DC generator set in order to transform the AC into a DC. It is a confirmation technique for the serious cases. The number of batteries and their connections would be based on the maximum required current by the full load of the protective network in the station.

4- Heaters

Mainly in power stations, the fuel may be a cock or liquid with high viscosity factors so that a tool for its liquidation process may be necessary. This to make the pumping process easier as well as we need the heating effect to modify the heat transfer processing and to raise the thermal efficiency even for all types of fuels.

5- Air Compressors

In the case of Air blast CB, a station for the air generation will be needed. The design of the compressed air station with its piping to both levels of voltage or more could be determined according to the layout of the electric station. It is shown in Fig. 11 - 9 that the compressors are installed in the mid place between CB of both sides. Assuming that the capacity of air of the HV CB is 3 times that of the LV CB, we can determine the best allocation for the compressors.

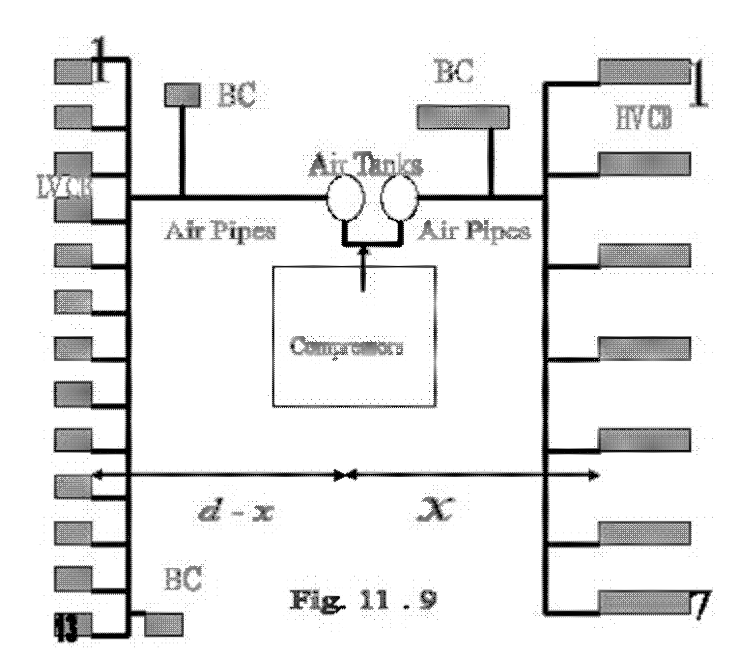


Fig. 11 . 9

It should be mentioned that the generated air will be at a higher pressure (approximately twice the required rated pressure for the CB) and consequentially a reserve compressed air will be available. The allocation depends simply on the air distance to travel. If the distance between CB of both sides is d and the compressors should be allocated in between at a distance x from HVCB site, the volume of air required for each LVCB may be supposed as V and so for the HVCB will be 3V.
For simplicity the CB in each side may be transformed into an individual CB as given in Fig. 11 - 10. The equivalent single HVCB will be put at the midpoint between both terminal CB as shown in Fig. 11 - 10. Similarly, the equivalent single LV CB will be at the

midpoint between the extreme ones. Then, the volume required for the both deduced CB (Fig. 11 - 10) will be n V and N (3V) for LV and HV respectively. Then, the distances must be proportionally measured with transmitted distance as:

$$N\,(3V)\ /\ n\,V = x\ /\,(\,d - x\,) \qquad (11\text{-}11)$$

Where
N is the number of HV CB
n is the number of LV CB

Thus, the distance x can be determined as:

$$x = 3dN\ /\ (n+3N) \qquad (11\text{-}12)$$

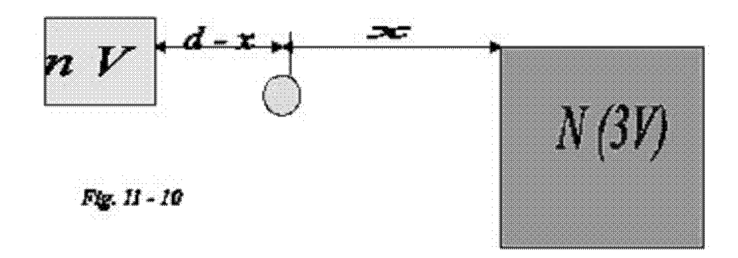


Fig. 11 - 10

The exact allocation of BC in both sides has been neglected because not only the final result will not be highly affected, but also the approximation in the actual implementation would be considered.
In the given example there are 15 and 8 CB in LV and HV sides, respectively. If the distance between both side d is 100 m, the variable x will be

$$x = 3\,(100)\,(8)\ /\ (15 + 3 \times 8\,) = $$
$$= \quad 2400\ /\ 39\ =\ 61.5\ \text{m} \qquad (11\text{-}13)$$

It is clear that the BT has been considered in the calculation exactly.

6- Control Room

It is one of the most complicated item in the design of a station due to the contents inside. These contents may be indicated shortly as:

a) The main Board

It contains the complete single line diagram with the ability of switching from it. The status of CB is indicated always and it illustrates any abnormal operations or faults. This is the large type of boards while there are many other small for different purposes.

b) Automation

The principle of supervision may be designed either Half or Full automated with a continuous dispatching control. Also, the modern types of station permit the application possibility of Internet Concept.

c) Indication Applications

All measuring instruments are installed to read in the control room mainly but the horning and flickering concepts must be the basic rules for the supervision goal. The continuous readings can be implemented in the control room but the minor readings can be at the site of the element in the cell. All major indicators must be in the main boards of the control room.

d) Synchronism

A major switch board is the synchronizing board which is the common tool for the switching on of any part in the station to the other or any part in the station with the network. It depends on the three factors (Voltage, frequency and phase sequence) to synchronize the connection and to ensure that both sides before connection can be connected.

e) Lay Out of The Control Room

It is easy to understand the lay out of a control room as it represents the station to a certain scale. The main board should be at the front where other boards will be behind (Fig. 11 - 11) . It is shown that a board or more represent a cell as a minor board while the main board contains the indication for any board inside the control room.

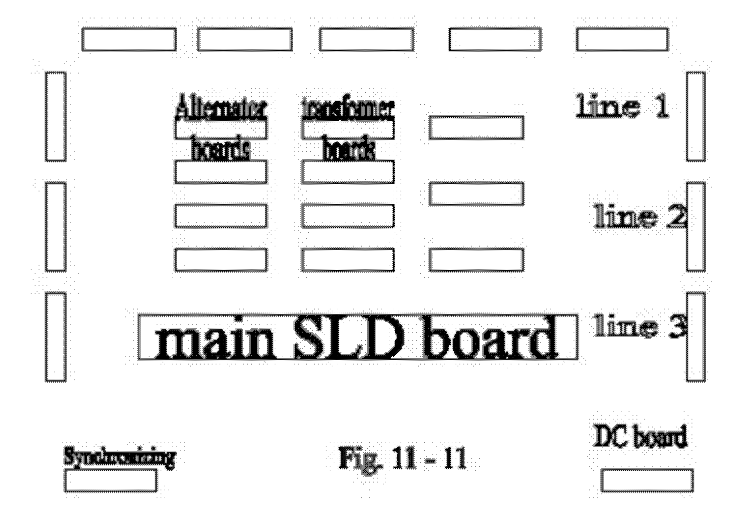


Fig. 11 - 11

f) Fire Fighting

It is very important to be installed and it must be checked regularly to ensure the security and safety of the station. It always works automatically according to the specification concerning the environmental rules. There are two main concepts for such item as the CO_2 or the spray of water. The automatic operation is the best.

10- Others

All other loads either personnel or that for a device or equipment may be included in the SLD of the distribution pert in the station. These elements are explained with the chapter of SLD before.

Earthing can be an important item in this case to protect both human and equipments against touch voltage.

11 - 5: ECONOMIC CONSIDERATIONS

The engineering design of a station is based mainly on the economic principle that means the most practical with highest quality. This highest level may be very expensive so that we must choose the !00 % solution or the nearest one with the minimum cost. Such choice should have all technical and engineering requirements without any loss in the major performance. So, the economic consideration would be a design factor for either the manufacturer or the designer. This may be also, the foundation for the calculations of tenders by the contractors or even for the receipt process by the authorities or companies in concern.

1- Basics

In the marketing field the price of a product depends on both offer as a supply and need (buying) in order that the price of a product will be dynamically varied. It is not the unique reason for such change but the inflation rate enforced the market to raise continuously the price. Thus, the cost could be subjected to any changes as a function of time. Therefore, the cost of a project in general should be evaluated for a specified short term of time. This term may be considered as 3 - 6 months according to the state. The supplier must implement all his works on the basis of a schedule to avoid himself from the penalty rules. Any contact for a project should have a determined requirements as:

a) Schedule

It is an application that put the time of pay and that for supplying the devices and equipments. The installation limit time must be indicated. The time of testing, training, spare parts supply, guarantee and the penalty points with respect to each item.

b) Penalty System

This factor limits any relaxation in the implementation of a contract and to ensure the best work level. It includes not only the late applying but also the concept of completing the work if the contactor is stopped.

c) Financing supply

The local law controls this item such as the percentage financing supply during the implementation of the work. Also, the insurance back up principle would be pointed from the beginning.

d) Specifications

The standard specification must be clearly indicated either from the technical or engineering point of view. The high quality may be a positive requirement in spite of the un-concrete values instead of the exact digits. This opens the market in the front of the suppliers. The standard specifications should be determined according to the international standards to be not suitable for a certain manufacturer or a single producer. This must be in a range of standards to give the chance for a lot of producers to enter the process of application as well as it will get you able to choose the best tender between all. This may lead to minimize the cost proposed for a certain producer. We never cannot remember that the choice of the best technical specifications will take the priority to the head. Then, the engineering requirements will appear as the boundaries of both technical and economic considerations. This requirements protect all processes in the concern such as the quality control, the modern products, the different stages of installation from the beginning to the end as it would be clear in the next items.

2- Cost of Elements

A station consists of different cells, auxiliaries, devices, equipments and others so that its bulk cost begins at the first element in any device. We should propose the rang of its price during the period from the time of costing to about one year later. This because the decision cycle may consume half a year and then the marketing study would be a major item.

This idea can be translated automatically into a cell price, devices, transformers, alternators, ... etc. Thus, engineers would tabulate these results of marketing to make it easy for designers or the workers in that field.

Therefore, tables for each element must present the price growth each time term as shown in Table 11-10. This table may be tailored for many manufactures or countries according to the quality level must be achieved. Updating for such Table may be very important to facilitate the process of costing when required. From such concept another Table can be deduced as given in Table 11 - 11.

Table 11 - 10: Element Price in the market of Germany (units $).

Element	1 year ago	now	6 months later	1 year later

Table 11 - 11: Cell Price according to the voltage level.

Voltage level, kV	1 year ago	now	6 months later	1 year later
11 66				
220 330				

This table would be repeated for other contents such as alternators, boilers, transformers, ... etc.

Otherwise, the pricing may be preferred to be classified according to the type of the part interested such as:

a) Electrical Cost

In this section the elements will be that of the electrical parts of the contents and then a cell can be evaluated as given before.

b) Civil Cost

There are many important works such as portals and foundations of the electric components such as isolating link, CB or CT and VT, ... etc. Also, the earthing ground under the land surface can be sectionalized into the electric part and the civil works accompanied with it. This is an example besides many other application such as the rail ways required for the transformers and others.

c) Mechanical Cost

In this section the compressors, boilers, loading of different components during the work may be the aim and thus, their evaluation and tabulation can implemented individually such that of the case of civil parts and electrical ones.

d) Cost of Auxiliaries

The pricing of auxiliaries in a station may be very important because it takes a suitable finance in the station cost in spite of its low percentage in the overall pricing. It appears to be more difficult because it contains many items. They also may cover electric, mechanical, chemical, civil styles and more so that they would be importantly introduced and all prices related can be also tabulated.

4- Working Operation Requirements

The above items considered reflect the shown materials for pricing but there are different costs that takes a lot of the total cost. This item related to different stages of installation to safe the equipment and worker against hurts. They may be shortly indicated as:

a) Storing

The storing of the products from the beginning till the final installation is important because it should be safe from stolen or damage. Any possible danger must be avoided and the schedule of transportation relative to that of installation would be synchronized to cover such cases. The places of storing must be in a good suitable weather. Different measurements can be checked always to protect them inside the site of storing.

b) Transportation

The process of transportation of the big equipment such as transformers and alternators of large electric stations provides an attached requirements for the implementation. It includes the technology of shipping and lifting such elements from the ground to above the transmitters and then to lay them again to the ground either at sores or at the site itself directly. This stage is not appeared materially but it consumes a lot in the cost of a station due to the need for experts in the supervision of the steps of transportation. In some cases, the Hydrogen may be a tool for the storing and so, a danger would be taken into consideration. The modern technology makes this process may it more easier but the risk factor must be introduced the design Tables. Thus, a table for the transportation must be prepared regularly. It should be indicated that the price growth will be slower than the for devices and elements.

c) Training

One of the most important factors in the evaluation of a project is the training style and its level because this training reflects the level of operation of a station. This means that good training will be a positive to protect a station and to maintain it for a long time. This training can be transferred into money to be added to the list of costs of a station. It can also, be tabulated with different levels of training and the number of trained persons *as well as their educational level.*

d) Testing

The receipt process is the good tool as it gives a measurement qualified for the decision of receipt of a station. Testing here can be stated as a specification title because it should be carried according to the technical specifications. The final decision for the receipt will mainly depend on the testing results. The consumption of time and tools may be transferred into money so that it may be tabulated as a product as explained above.

e) Guarantee and Maintenance

Finally the grantee as well as the maintenance would be a technical condition to safe the station against the quality of components, This means that the period of maintenance after the final receipt would be a differential factor in the final decision when a person evaluates the project. It also, can be tabulated as a cost value like other components discussed before.
The final cost would be tabulated as given before to gather first each item and then for each level of voltage. This can be expanded to gather the cost for a station as a whole such as equipment and then as a summation of equipment and the last factors in the section of cost of working operations. This means that the costing process is a cascading style phenomenon.

11 - 6: PROBLEMS

1. Evaluate the area of a 220 kV cell for a transformer in a station.

2. Compute the different heights for the trusses in a normal *110 kV transmission cell*

3. Deduce the different levels for the HV wires in a transformer cell at 110 kV and then compare the results with 220 kV cell.

4. Find the ratio between corresponding heights for both levels of a 132/500 kV transformer cell.

5. Determine the ratio between maximum wire heights for a transformer and a potential transformer 110 kV cells in a station.

6. Get the percentage increase in the maximum wire height for a 66 kV transformer cell and Bus tie cell on the same bus bar.

7. Deduce the ratio between the maximum wire height for a transformer 400 kV to that of a Bus coupler cell in the same yard.

8. Compute the percentage increase in the height of trusses in the transformer 220 kV cell if the reverse return style is applied.

9. Calculate the saving in the area of a transformer cell if it is based on the reverse return style with respect to the sequential type connection.

10. In a 132 kV yard of a substation, there are 14 cells as: (2 transformers, 2 Bus coupler, 2 bus tie, 4 potential transformers and 4 lines). Calculate the percentage saving area in if a transformer cell is based on the return reverse style in the cell connection. Derive the saving in the station area if the potential cells are reduced to only two cells.

11- Design the bus bar section for a *500 / 220* **kV step down transformer of** *130 / 120 MVA*, **which is feeding** *4 x 30 MVA, 220 kV,* **transmission lines. Give the wiring and mechanical calculations if the maximum allowable tension is 20 000 Ib. The spacing between phases may be 6** *m* **and the 20 kV cell width may be 18** *m*.

12- Design the single line diagram for two different distributions in the above problem 1 and deduce the distribution of currents in branches as well as the distribution of node voltage in the connection scheme in each case.

13- For the above problem check the corona effect and redesign the wiring diagram if needed and the rupture capacity of line circuit breaker. Assume any additional data to find the requirements.

14- In the above problem 3 if the double B.B. system is used, find the total cost of such a part in the station installation. Assume that the CB cost is 70 times that of isolating link. The conductor costs 10 L.E./ m, insulator 100 L.E. / dish and you can suppose the other prices. Give your calculations in details.

15- Write a computer program to design a section as in the problem No. 11.

16- Calculate the complete cost for the equipment and materials used in a power station containing:
a) 2 x 400 MVA alternators, 33 kV ,7 x 10 MVA feeders, 33 kV
b) 6 x 120 MVA, 33/220 kV transformers, 18 x 40 MVA, 220 kV lines
c) 2 x 5 MVA, 33 / 11 kV auxiliary transformers.
Tabulate all results in details.

17- Put the details of calculation for a tender to install the above station if the land costs 1000 L.E. / m^2 & you have the following equations and constants:

$$\text{Price of CB} = (kV)\ e^{P} + A$$

$$\text{Price of Isolating Link} = B\ (kV) + C$$

$$\text{Price of trusses} = D\ (kV) + E$$

Table 11 - 12: Constant Values

Voltage	A	B	C	P	D	E
220 kV	10 000	100	1000	100	100	15
33 kV	2000	100	10	10	100	10
11 kV	1000	10	100	5	500	50

18- In the above problem, derive the percentage saving in cost if the area distribution is based on horizontal installation for a cell instead the vertical one.

19. Evaluate the area of a 220 kV cell for a transformer in a station.

20. Compute the different heights for the trusses in a normal 110 kV transmission cell

21. Deduce the different levels for the HV wires in a transformer cell at 110 kV and then compare the results with 220 kV cell.

22. Find the ratio between corresponding heights for both levels of a 132/500 kV transformer cell.
23. Determine the ratio between maximum wire heights for a transformer cell and a potential transformer 66 kV cell in a station.

24. Get the percentage increase in the maximum wire height for a 33 kV transformer cell and Bus tie cell on the same bus bar.

25. Deduce the ratio between the maximum wire height for a transformer 500 kV to that of a Bus coupler cell in the same yard.

26. Compute the percentage increase in the height of trusses in the transformer 220 kV cell if the reverse return style is applied.

27. Calculate the saving in the area of a transformer cell if it is based on the reverse return style with respect to the sequential type connection.

28. In a 132 kV yard of a substation, there are 14 cells as: (2 transformers, 2 BC, 2 bus tie, 4 potential transformers and 6 lines. Calculate the saving in the area in percentage if the transformer cell is based on the return reverse style in the cell connection.
Derive the saving in the station area if the potential cells are reduced to only two cells.

STATISTICAL TRANSIENTS

Transients in a power system form - to a great extend - the shape of the operation for a system under steady state conditions so that its study for the design a power system elements may be a subject of great interest. Transients in power systems takes two fundamental form where they may be either Electromagnetic or electro-dynamic transients.

However, electro-dynamic transients controls the design of the alternators in power stations as well as the restrictions for their operation in the network. This case concerns the stability of operation in electric networks while the second type of transients (Electromagnetic transients) is related to the insulation level. There are two types of Electromagnetic transients as External and internal transients while the last (internal) transients play a fundamental roll for the determination of the insulation level of a component.

Therefore, transients take a great importance with the EHV and UHV levels where it is a major factor for either stations or transmission lines. For lines, the insulating string depends on such calculations due to the switching processes cause a great increase in the insulation level. EHV and above depends on the switching transients although LV lines determines the External lightning strokes take the action instead.

12 - 1: PROFILE

Since the subject of transients contains a lot of symbols, it has been indicated the most of these symbols as an introduction for the proposed item.

1 - Symbols

Accordingly, the most important of symbols that may be introduced in the proposed subject here may be tailored in a series of Tables. This leads to that we may abstract the item and shorten it in a specific details inside a very small area of the transients.

This means that the subject of transients as a whole subject will not be presented in this chapter due to the great volume of such item. It is reflected on the design of station for the string length either inside a station or for transmission lines. Therefore, the study for a transient profile in transmission lines may be a mirror view for the effect of transients on the insulating strings either for towers or portals inside a station. It is similar for BB in stations from the point of string length.

The main parameters of a transmission line may be introduced as their symbols are listed in Table 12- 1. Also, these parameters will be given in the mathematical analysis for the determination of a transmission line profile so that it may be used in steady state too. This leads to indicate that these symbols are widely used but other symbols for the same term may be given in other papers or books or references in general.

Table 12- 1: The main parameters of a line

Symbol	meaning	symbol	meaning
[Z]	Impedance matrix	R_g	Ground resistance
[R]	Resistance matrix	L_s	Self inductance of a line
C_s	Self capacitance of a line	L_m	Mutual inductance of a line
C_m	Mutual capacitance of a line	*L*	Line length
R_c	Conductor resistance	[X]	Inductive impedance matrix

Whatever, the acting values in the system of a network may be expressed as tabulated in Table 12 – 2. These values appear to be the voltage and mainly.

Table 12 – 2: Acting values in the transmission line performance

Symbol	meaning	symbol	meaning
Z_1, Z_2	Characteristic impedances	Z_c	Surge impedance
x	Distance measured from the sending end of a line	ω	Angular frequency
E_r	Voltage at the receiving end	L_{supply}	Current at the receiving end
$V(l)$	Voltage at the receiving end	$V(x)$	Voltage at a point x
$I(l)$	Current at the receiving end	$I(x)$	Current at a point x

Transient parameters for the transmission line performance may be indicated as seen in Table 12 – 3 where the propagation factors may be appeared.

Table 12 –3: Transient parameters for a line performance

Symbol	meaning	symbol	meaning
α, β, θ	The three wave mode coordinates	[T]	Transformation matrix
$\gamma, \gamma_1, \gamma_2$	Propagation coefficients of a line	A , B	Elements of the transformation matrix (A = 1.2 , B = 1.8)
λ_1, λ_2 and λ_3	Roots of the characteristic equation for the propagation coefficients variable	V_o	Average over-voltage
DTR	Distribution to transmission ratio	*TN*	*Transient Number*
$\Sigma(Z_l)_T$	Sum of the impedance of lines in the transmission system	$\Sigma(Z_l)_D$	Sum of the impedance of lines in the distribution system

Then, a high mathematic would be needed for such calculations because it depends on the *LAPLACE* and its transform in the time domain. It takes a formula that a special mathematics at different initial condition may be necessary. Also, the computer facility makes this easier where it is mainly, here, related to the switching transients for transmission systems on the basis of statistics. So, different terms or transient factors, as symbols will be used specifically in the present book, are listed here in Table 12 -4.

Table 12 - 4: List of symbols

Symbol	meaning	symbol	meaning
σ	Standard deviation	GR	General ratio
N_t	Number of points of transients inside the time length	K	Total Number of points inside the time length
T_0	Time interval duration	TN_G	General transient number
$(N_t)_D$	Transient number for the distribution system	$(N_t)_T$	Transient number for the transmission system

Shunt capacitors are installed in large distribution systems and so, many critical nodes may be appeared. Transient processes in a power network may lead to a damage for the operation either partially or completely in spite of the relation to the operation system itself. Otherwise, the switching transients may be internal or external and consequently, the study of such item must be significant to bring the system to the safe and suitable zone. Also, the transient phenomena can be occurred either for a long time length such as electromechanical type or for a short time as the electromagnetic switching processes. This subject takes the action with both transmission and distribution systems so that it may be investigated

more and more in future. The impedance Z of a symmetrical line as a function of its parameters (conductor resistance R_c and ground R_g as well as self inductance L and mutual M) may be formulated as given by:

$$[Z] = [R] + j\,[X] = \begin{pmatrix} R_c+R_g & R_g & R_g \\ R_g & R_c+R_g & R_g \\ R_c & R_g & R_c+R_g \end{pmatrix} + j\,\omega \begin{pmatrix} L & M & M \\ M & L & M \\ L & M & M \end{pmatrix} \qquad (12 - 1)$$

2- THEORETICAL ANALYSIS

There are some different approaches tried to regulate the parameters of a power system generally. Others went to transmission lines or even to change the concept of transmission but the final practical solution requires more effort.

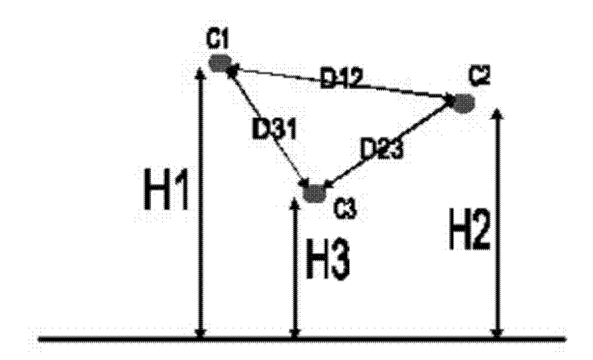


Fig. 12 - 1: The geometry of conductors

Also, there are new types of lines such as flexible AC transmission systems FACTS. The switching transients depends to a great extend on the parameters of the system where the ground return effect plays an important role. The earth will be considered as a homogenous for simplicity and so, the Carson concept would be applied.

Otherwise, the capacitance is taken as a constant without any ground effect while the frequency dependent parameters are introduced. The self capacitance will be C_s and the mutual will be C_m.
Hence, this paper studies both systems transmission (500, 330, 220, 110 kV) and distribution (35, 10, 6 kV) as sample for any network in order to conclude the statistical performance for a system under the transient conditions. Hence, the random five values for the switching angle are applied to present the general case of switching transients. The overall geometry of phases on standard towers, as shown in Fig. 12 - 1, is listed in Table 12 -5.

Table 12 -5: Dimensions for the considered towers

Type	Tower	kV	Dimensions (m)					
			H1	H2	H3	D12	D23	D31
Out door	Metal	500	20-19	20-19	20-19	11-13	11-13	22-26
		330	16-30	16-23	16-23	8.5-9.4	8-8.6	16-7.5
		220	18.5-30	14-24	14-18	6.8-7.1	6-6.86	6.8-13
		110	15.5-18	12.5-15	12.5-12	4.24-3.27	5.5-3.27	4.24-6
		35	12-17.5	9-14.5	9-11.5	3-3.08	3-3.06	4.24-6
		6-10	9-8.9	9-7.6	9-7.6	1.5	1.5	3-1.5
Out door	Wood	220	12	12	12	5	5	10
		110	9	9	9	4	4	8
		35	11	11	11	3	3	6
		6-10	9.5	8.75	8	1.5	1.5	1.5
In door	Metal	220	5.3	3.5	1.7	1.8	1.8	3.6
		150	3.5	2.3	1.1	1.2	1.2	2.4
		110	2.3	1.5	.7	.8	.8	1.6
		35	0.93	0.61	.29	.32	.32	.64
		20	0.58	.38	.18	.2	.2	.4
		10	0.38	.25	.12	.13	.13	.26
		6	0.29	.19	.09	.1	.1	.2
		3	0.205	.135	.065	.07	.07	.14

It is required to illustrate the objective aim of the study where certain national power system cannot be identical to the other.

Then, the determination of a general performance for all networks through the investigation of any one may take us away from the actual condition in the site. However, the transient characteristics depend on mainly the parameters of a system where their values can be evaluated through the geometry of phases. This means that the geometry allocation of phases will reflect the overall behavior in the domain of electromagnetic transients.

Therefore, the classes of distribution and transmission can be taken as the gate to solve such problem and consequently its generalization may be implemented. This projects the idea of the presented work according to the evaluation of the boundaries for the profile of switching transients in power system. The investigation may be tailored into two steps. The first will be for each system (Distribution or transmission) while the second deals with the statistical variation in length or voltage or even in the percentage content of a system relative to the other inside the network.

After that, the general profile can be computed for different values of content ration (Distribution to transmission ratio). Otherwise, the data cannot be based on the population readings so that the statistical sampling processes must be inserted. The main equations of voltage and current at a point x of a line are given in a matrix form:

$$-d/dx\,[V(x)] = [Z]\,[I(x)]$$
$$-d/dx\,[I(x)] = [Y]\,[V(x)] \qquad (12\text{-}2)$$

Also, the deduced Voltage at a point x with the help of Sylvester theorem may be found as:

$$V(x)= 1/3\{ch\,\gamma_1(l-x)[M_1]+ch\,\gamma_2(l-x)[M_2]\})\,[v(l)]+1/3\{\,Z_1\,sh\,\gamma_2\,(l-x)[M_2] + Z_2\,sh\,\gamma_1(l-x)\,[M_1]\})\,[I(l)] \qquad (12\text{-}3)$$

Where

$$[M_1]=\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}, [M_2]=\begin{pmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{pmatrix}$$

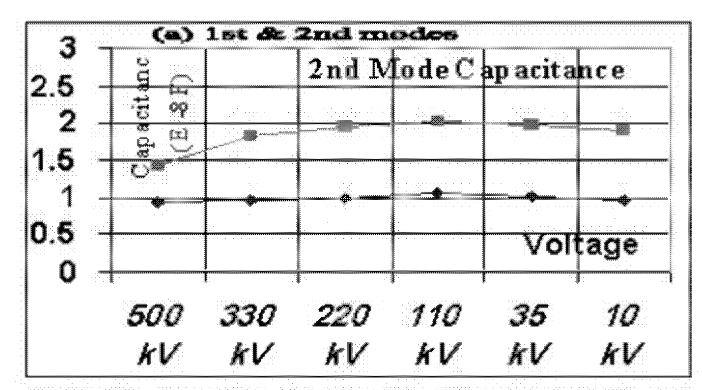
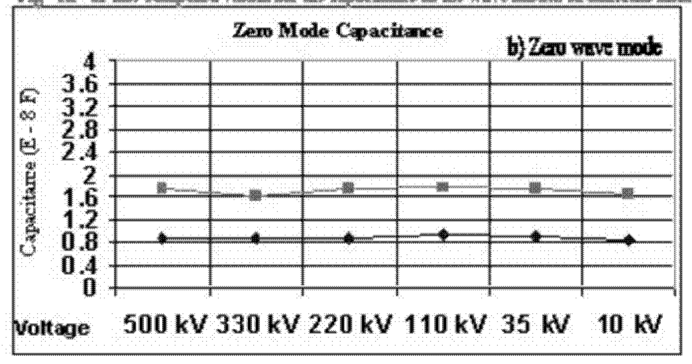


Fig 12 - 2: The computed values for the capacitance in the wave modes of different lines



and also,

$$Z_1^2 = \frac{R + p(l-M)}{p(C- C_m)} , \quad Z_2^2 = \frac{R+3R +p(L+2M)}{p(C+2 C_m)}$$

Otherwise, the current can be derived as:

$$[I(x)]= \{ sh\ \gamma_2\ (l-x) [\ Z_c]^{-1}\ [v(l)] + ch\ \gamma_1\ (l-x)\ [I(l)] \qquad (12-4)$$

The replacement of the matrix of propagation coefficient by a multi term equation according to the rule of *Sylvester* will simplify the derived formula for the propagation coefficient γ

$$[\gamma] = 1/3\ \lambda_1\ [M_1] + 1/3\ \ \lambda_2\ [M_2] \quad (12-5)$$

where

$$\lambda_1^2 = \gamma_1 + 2\ \gamma_2\ \&\ \lambda_2^2 = \lambda_3^2 = \gamma_1 - \gamma_2$$

Then, the formula of the propagation coefficient appears to be in the form:

$$e^{[\gamma]x} = 1/3\ e^{\lambda_1 x}\ [M_1] + 1/3\ e^{\lambda_2 x}\ \ [M_2] \qquad (12-6)$$

3- MODAL COORDINATES {(α),(β), (0)}

This modal coordinates transform the differential equations into linear simple equation but in the frequency domain. Whatever, the reverse solution will be more complicated for the non-transposed lines in the *Laplacian* domain and so the final formula can be solved in the wave mode coordinates. On the other hand, the distribution power networks plays an important role in the processes of operation

and many papers were analyzed this system as in. The modal technique gives the simplicity for the solution of such problems in the complex plane so that the main parameters of the deduced equation (12 -6) may be applied in each of the modes of the analysis.

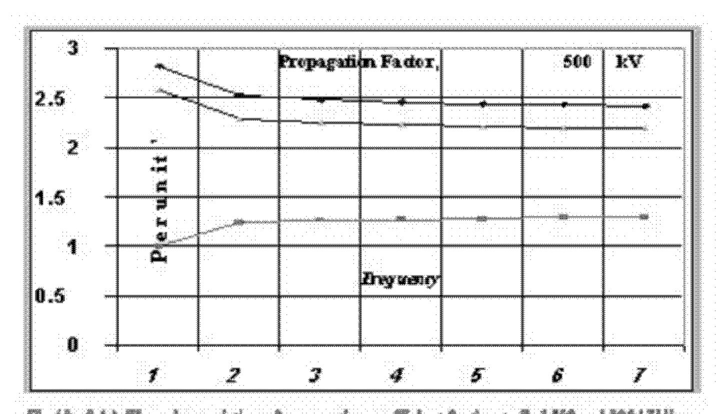
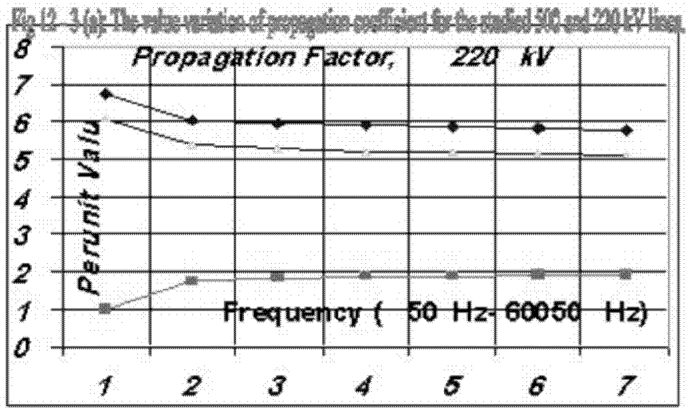


Fig.12 -3 (a): The value variation of propagation coefficient for the studied 500 and 220 kV lines.



The modes are individual channels without any mutual relationship between them and they defined as {(α) , (β), (0)}. Therefore, the

parameters of the system must be evaluated. So, a capacitance is calculated for different phase geometry shapes in modal coordinates as shown in Fig. 12 - 2. Two limits (upper and lower) are indicated where both channels { 1^{st} (α) & 2^{nd} (β) } have a higher value than that for the zero wave mode(0). It is increasing with voltage level in the two modes but it is a constant in the zero mode. The propagation coefficient is varied in these coordinates a shown in Fig. 12- 3 (a) and (b) where per unit system is considered.

The frequency presence inside the processes of transients may reach 60 kHz due to the HF loads and interference with electromagnetic fields. The 50 Hz t zero mode position is taken ass the reference (unity value) and then its value is illustrated for studied voltage levels. The coefficient is increasing with frequency in Zero mode coordinates while it is decreased in other channels. The maximum ratio of this coefficient is appeared for 110 kV, where the 35 kV distribution lines approaches the case of 500 kV. This approves that the distribution network is subjected normally to heavy transients relative to its level where its value my exceed that for EHV levels. This coefficient can be shown mathematically in each channel from equation (12 -6) to obey the formula 12 -4:

$$e^{[\gamma]x} = e^{\gamma_\alpha x}\{(\gamma_\beta - \gamma)(\gamma_0 - \gamma)\}/\{(\gamma_\beta - \gamma_\alpha)(\gamma_0 - \gamma_\alpha)\}$$
$$+ e^{\gamma_\beta x}\{(\gamma_\alpha - \gamma)(\gamma_0 - \gamma)\}/\{(\gamma_\alpha - \gamma_\beta)(\gamma_0 - \gamma_\beta)\} + e^{\gamma_0 x}$$
$$\{(\gamma_\alpha - \gamma)(\gamma_\beta - \gamma)\}/\{(\gamma_\alpha - \gamma_0)(\gamma_\beta - \gamma_0)\} =$$

$$= e^{\gamma_\alpha x}\begin{pmatrix}1 & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & 0\end{pmatrix} + e^{\gamma_\beta x}\begin{pmatrix}0 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 0\end{pmatrix} + e^{\gamma_0 x}\begin{pmatrix}0 & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & 1\end{pmatrix} \qquad (12\text{-}7)$$

On the other hand, the attenuation factor plays great role in the limitation of the over-voltages since it is representing the effective part of the propagation process. The characteristic is shown in Fig. 12 - 7 where the maximum ratio is corresponding to the higher voltage class. However, the wood tower standards give a lower

attenuation so that its value for 35 kV towers may exceed that for the 110 and 220 such towers. The derived equations will be more complicated for the non-transposed lines in the *LAPLACIAN* domain (p) and so the initial formula can be solved in modal coordinates.

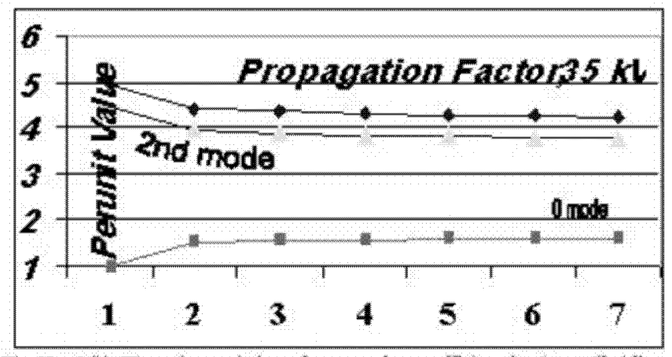
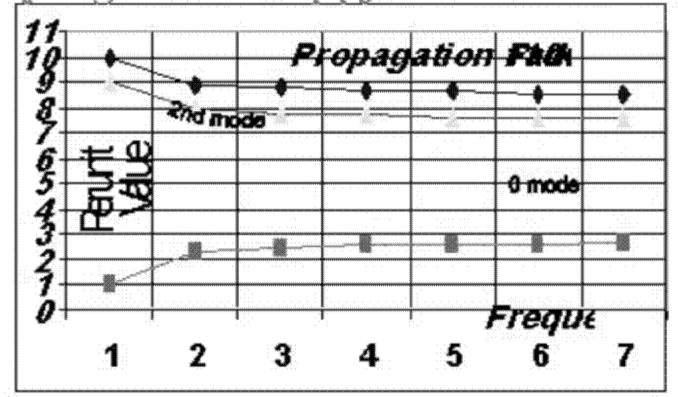


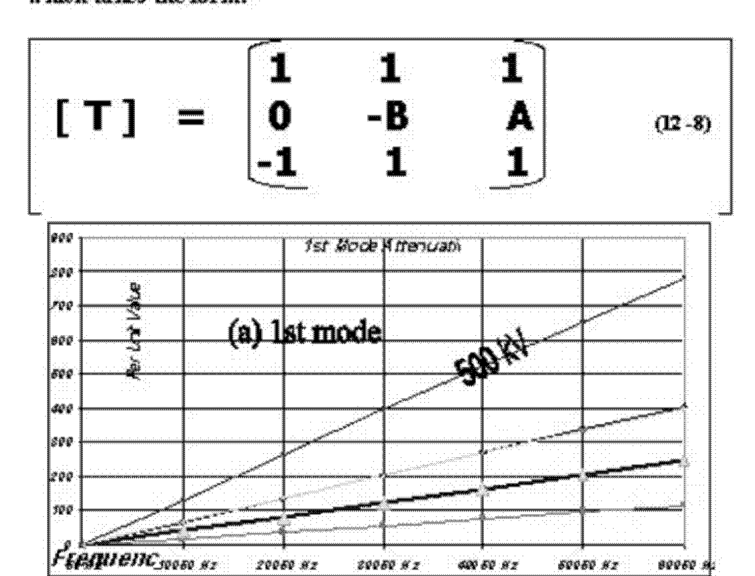
Fig 12 - 6 (b): The value variation of propagation coefficient for the studied lines.



Also, the distribution networks play an important role in the operation conditions s analyzed before. Many methods are known for the transient calculations and the wave mode propagation

method will be selected because it is valid for either transposed or non-transposed lines. It depends on the transformation matrix [T], which takes the form:

$$[T] = \begin{bmatrix} 1 & 1 & 1 \\ 0 & -B & A \\ -1 & 1 & 1 \end{bmatrix} \qquad (12\text{-}8)$$



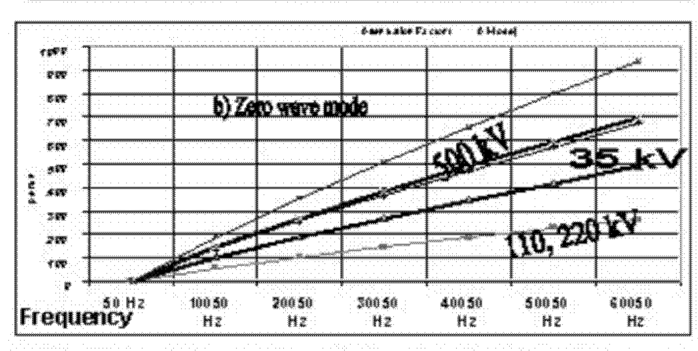


Fig. 12 - 4: The variation performance for the attenuation factor with frequency

If the basic differential equations (12 -2) are specified to the modal coordinates, new - deduced expressions become individually:

$$-d/dx\,[V(x)_{\alpha,\beta,0}] = [Z]\,[I(x)_{\alpha,\beta,0}]$$
$$-d/dx\,[I(x)_{\alpha,\beta,0}] = [Y]\,[V(x)_{\alpha,\beta,0}]$$

(12- 9)

Then, voltage and current at point x in modal coordinates will be in the form of

$$[V(x,p)]_{\alpha,\beta,0} = [\mathrm{ch}\ \gamma(l-x)]_{\alpha,\beta,0}\,[V(l,p)]_{\alpha,\beta,0} + [\mathrm{sh}\ \gamma(l-x)]_{\alpha,\beta,0}\,[Z_c]_{\alpha,\beta,0}\,[I(l,p)]_{\alpha,\beta,0}$$
$$[I(x,p)]_{\alpha,\beta,0} = [\mathrm{sh}\ \gamma(l-x)]_{\alpha,\beta,0}\,[Z_c]^{-1}_{\alpha,\beta,0}\,[V(l,p)]_{\alpha,\beta,0} + [\mathrm{ch}\ \gamma(l-x)]_{\alpha,\beta,0}\,[I(l,p)]_{\alpha,\beta,0}$$

(12 -10)

These equations depend on the transformation of the phase system into another one, which is known as the wave mode system. This means that the wave modal concept has three isolated modes without any mutual effect between them as this can be reached through the mathematical theorem of *Eigen values* and *Eigenvectors*. It should be noted that the transformation matrix of Eq. 12 – 8 is the *Eigenvectors* for the system. A special program is used for the calculations of parameters in wave modes or the transients and modified to measure the statistical values as presented here. The application of parameters in modal axes is based on the matrix equation:

$$[E] = [T][Z_c\ \mathrm{ch}\ \gamma l\ /\ \mathrm{sh}\ \gamma l] \times [T]^{-1}[I(0)] \quad (12\text{-}11)$$

For easy computation these equations must be referred to the voltage source at the sending end instead of the voltage at receiving end. Then, a simplified formula for voltage and current can be expressed as

$$[V(x,p)]_{\alpha,\beta,0} = [ch\ \gamma x]_{\alpha,\beta,0}\,[V(0,p)]_{\alpha,\beta,0} + [sh\ \gamma x]_{\alpha,\beta,0}\,[Z_c]_{\alpha,\beta,0}\,[I(0,p)]_{\alpha,\beta,0}$$

$$[I(x,p)]_{\alpha,\beta,0} = [sh\ \gamma x]_{\alpha,\beta,0}\,[Z_c]^{-1}_{\alpha,\beta,0}\,[V(0,p)]_{\alpha,\beta,0} + [ch\ \gamma x]_{\alpha,\beta,0}\,[I(0,p)]_{\alpha,\beta,0} \quad (12\text{-}12)$$

It is important to find the wave velocity in the proposed wave modes as shown in Fig. 12 - 5. It would be indicated that the voltage source differs from that at the sending end of line according to the relation

$$[V(0,p)]_{\alpha,\beta,0} = [E(p)]_{\alpha,\beta,0} - p\,[L_{supply}] \quad (12\text{-}13)$$

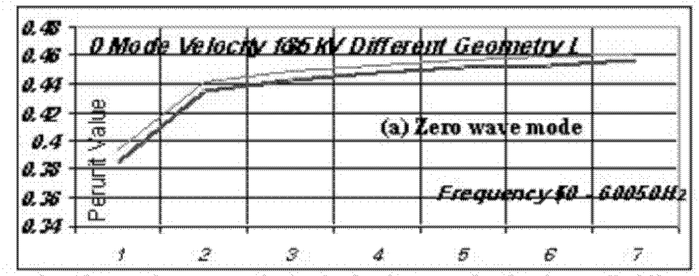


Fig. 12 - 5: The wave velocity in the three modes for the studied lines.

Consequently, the voltage may be formulated through the transformation matrix:

$$[V(x,p)]_{\alpha,\beta,0} = \{[\mathrm{ch}\ \gamma(l-x)/\ sh\ \gamma l]_{\alpha,\beta,0}\ [E(p)]\}/\{B\ [Z_c]_{\alpha}\{[\mathrm{ch}\ \gamma(l-x)/\ sh\ \gamma l]_{\alpha} + A\ [Z_c]_{\beta}\ \{[\mathrm{ch}\ \gamma(l-x)/\ sh\ \gamma l]_{\beta}\} \quad (12\text{-}14)$$

Therefore, voltages in phase coordinates can be determined numerically according to the convolution theorem as given in

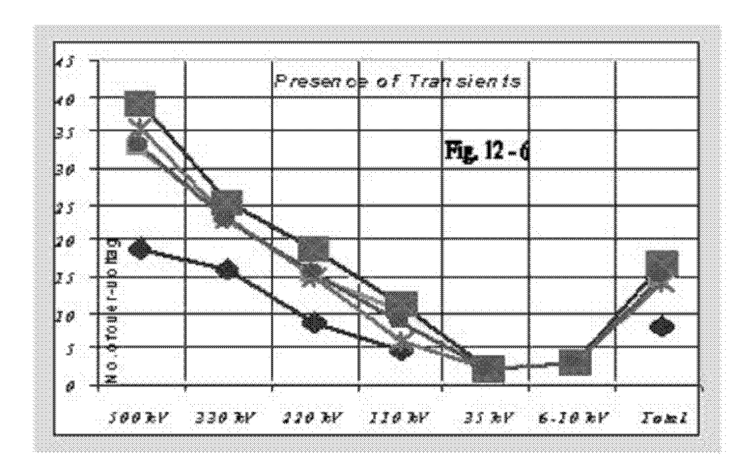
$$V_a\ (x,p) = A\ V_{\alpha} + B\ V_{\beta} + (A+B)\ V_0$$
$$V_b\ (x,p) = A\ B\ (V_{\beta}\ - V_{\alpha})$$
$$V_c\ (x,p) = A\ V_{\alpha} + B\ V_{\beta} - (A+B)\ V_0 \quad (12\text{-}15)$$

Similarly, the equations of currents in phase coordinates can be found, so the number of points of transients along the lines for both distribution and transmission systems in a percentage base (K=140, T=0.23 ms) can be derived as shown in Fig. 12 - 6.

12 – 2: STATISTICAL SWITCHING

Moreover, the variation of time domain length has been examined as given in Fig. 12 - 7. An interval duration of 0.21 ms was considered for 100, 200 and 400 points of calculation. Larger interval (T=0.23ms) was taken for 140 and 300 ms. The computed verge over-voltage V is illustrated in Fig. 12 – 7 (a) but the standard deviation is shown in Fig. 12 - 7 (b). The dependence of average value on time domain is deduced s time is changed from 21 to 64 ms (Fig. 12 - 8).
In the above results, the combination of changing of either interval or number of points in the domain length clarified the effect of steady state presence in long time term for 500 kV. The low voltage distribution system (6 - 10 kV) gives gradually decrease with time domain length while it is approximately constant for 35 kV. Also, the overall average voltage for studied lines is decreased due to the presence of steady state period inside the process of calculations.

Otherwise, the effect of interval only for a constant value for the points of computations (300) is considered and the results are listed in Table 12 - 7 for both verge voltage and standard deviation.



1- TRNSIENT NUMBER

The transient presence in a system during the switching processes my be important to measure the level of its action on the insulation level. The paper presents a number for such simulations. It represents the percentage presence of over-voltages inside the time length considered and so, it can be expressed mathematically in the form:

$$TN = N_t / K \qquad (12-16)$$

The presence of transients for each case is drawn in Fig. 12 - 9 a, but the overall presence is shown in Fig. 12 - 9, b. It is seen that the transients are always decreased with voltage level except some readings of 220 kV relative to 110 kV due to the closed dimensions of towers for both levels (Table 12 - 1). This voltage is decreased with respect to the interval, which reflects the total time domain length. This confirms the deduced results of Fig. 12 - 8.

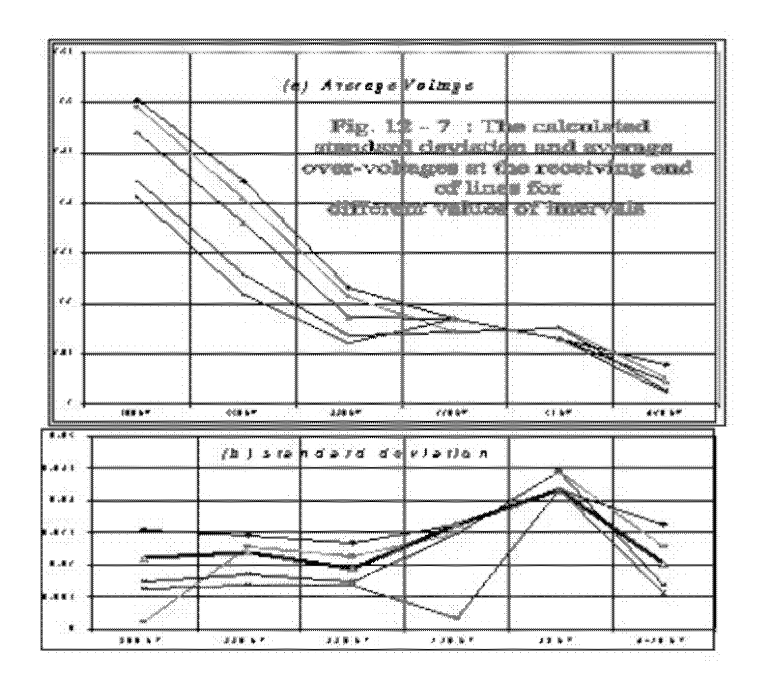


Fig. 12 – 7 : The calculated standard deviation and average over-voltages at the receiving end of lines for different values of intervals

Table 12 - 6: The calculated average (V_o) and standard deviation (σ) for transient for both distribution and transmission systems (K=140, T_o=0.23 ms)

Point / kV	L (km)	Sending End V_o	Sending End σ	At ¼ L V_o	At ¼ L σ	At ½ L V_o	At ½ L σ	At ¾ L V_o	At ¾ L σ	Receiving End V_o	Receiving End σ
500	500	1.067	.003565	1.211	.008909	1.336	.01245	1.359	.01317	1.295	.00117
330	300	1.072	.006459	1.159	.0102	1.221	.01281	1.235	.01352	1.203	.01278
220	200	1.056	[illegible]	1.091	.009596	1.121	.01058	1.136	.01116	1.107	.01125
110	100	1.05	.01194	1.044	.00861	1.054	.01017	1.061	.01054	1.072	.01488
35	30			1.075	.02439	1.075	.02439	1.075	.02439	1.075	.02439
6-10	10			1.027	.01281	1.027	.01281	1.027	.01281	1.027	.01281

Also, the same conclusion can be derived from Fig. 12 - 9, b. The calculated average value (V_o) and standard deviation (σ) for transient voltages along the lines for both distribution and transmission systems (K=140 and T_o=0.23 ms) is listed in Table 12 - 6. The results pointed that the most possible content for the transients in networks for such cases of EHV and UHV so that evaluation on switching transients would be inserted in the process of design in addition to the visibility study.

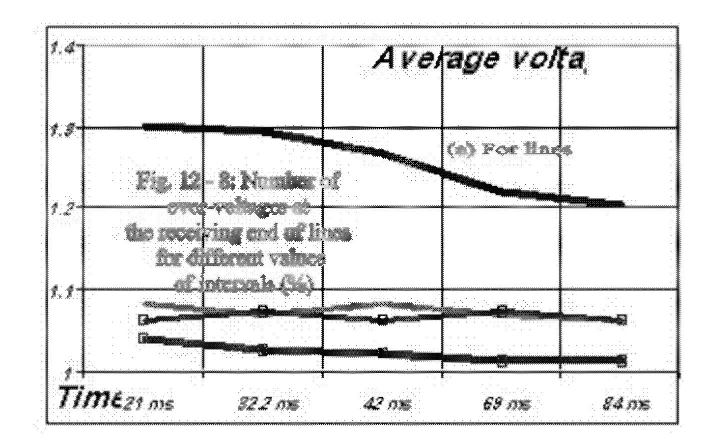
Table 12 -7: The deduced average voltage level and standard deviation σ at the receiving end of lines for different duration of intervals at constant value of intervals (K=300)

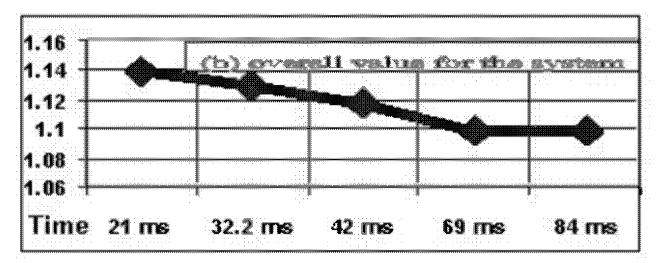
Interval duration (ms)

Voltage	.23		.22		.21		.2		.12	
kV	V_o	σ	V_o	σ	V_o	σ	V_o	σ	V_o	σ
500	1.221	.007315	1.23	007373	1.23	007972	1.223	007648	1.291	008629
330	1.129	.00846	1.135	.00902	1.135	.008887	1.156	009194	1.218	009699
220	1.069	.00739	1.075	007491	1.075	.008276	1.081	007405	1.123	.00754
110	1.072	.01488	1.085	.0147	1.085	.0162	1.047	008088	1.081	009005
35	1.075	.02439	1.065	.02348	1.065	.02144				
6-10	1.014	.006732	1.015	007079	1.015	.006912				

On the other hand, the effect of time interval in the calculations is analyzed where Table 12 -7 presents the deduced average voltage level and standard deviation σ for the voltage at the receiving end of a lot of transmission lines. It should be mentioned that the two levels of voltage for either the EHV transmission system as well as that of the 11 – 6 kV level for the distribution networks. This has been computed and repeated for different durations of intervals but at a constant value of intervals of K=300. This proves that smaller duration for the same interval gives an accurate results as the results of the table pointed to a higher value of average voltage.

2- COMPENSATION EFFECT





The reactive part of elements connected to a power system takes a part in the switching processes as soon as voltage control in the distribution system needs shunt capacitor on loads. This may be transferred (directly or non-directly) to the low voltage line in the case of heavy loads. This capacitor may be appeared also in EHV and UHV transmission systems. Whatever, the load type has been tested where both inductive and capacitive loads are introduced at the receiving end of the switched lines. Results are shown in Fig. 12 - 10 for the inductive condition for a time length of 200 points with 023 ms interval. It shows a normal characteristic while the heavy

transients appears with the second condition (capacitance).
It would be required to indicate that the capacitive effect reached faster in the distribution system. It began at 10 Ohms for 6 kV with a per unit value of 37.14 while this value became 16.82 for 35 kV lines. The other lines still in the normal but the resonance condition may come later. It varied with potential level as the final will be the highest one.
The resonance characteristics are shown through curves in Fig. 12 - 11 although the standard deviation became very large. This means that the value of actual maximum voltage is high. The curves for 220 and 330 kV are not illustrated. Fig. 12 - 12 shows well that the presence of transient inside the time length is higher with nominal potential and it is very high for the capacitive condition.

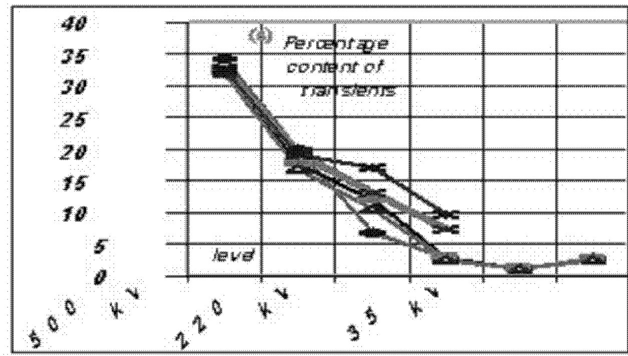
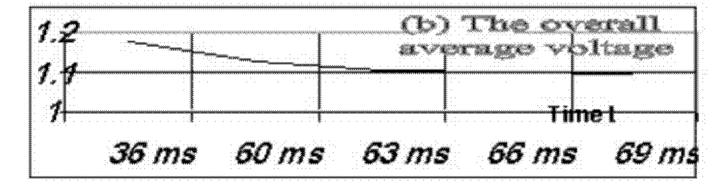
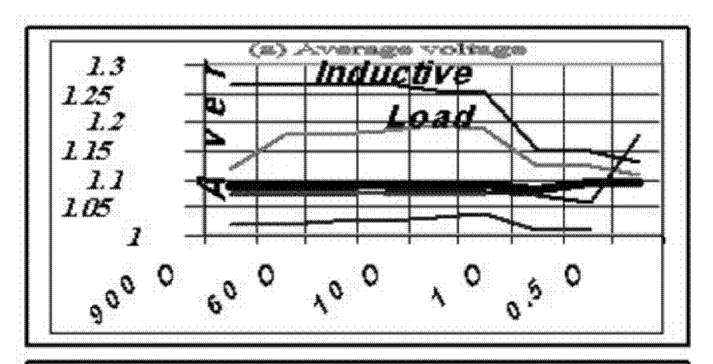


Fig. 12 - 9: The results for the considered lines at different duration intervals at a constant number of intervals (K=300)



The average voltage distribution at the receiving end of the lines studied but for all possible lengths is computed as given in Fig. 12 - 13. It proves that the switching transients in EHV and HV lines will have a great role in the design of such lines and it decayed for the distribution system.



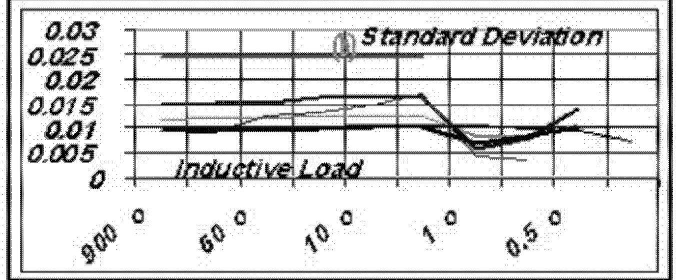


Fig. 12 - 10: The inductive load Effect on transient processes

Also, the effect of line length shows an average value for each length in spite of the different potentials (Fig. 12 - 13, b). The derived standard deviation is drawn in Fig. 12 - 14 with different lengths of lines when the transient number is presented in Fig. 12 - 15. These curves indicated the same conclusion defined above.

Nevertheless, the shunt compensation by the installation of rector at receiving end would be the best solution for long lines EHV and UHV systems due to the reduced statistical transient presence (as the value of TN).
Whatever, shunt capacitors on feeders of thee distribution networks represent critical condition with bulk reactive powers so that a great interest would be needed with sudden change of load according to the performance of load curves at such points.

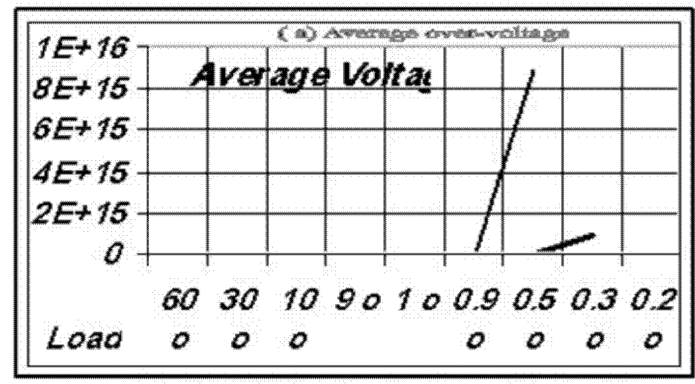
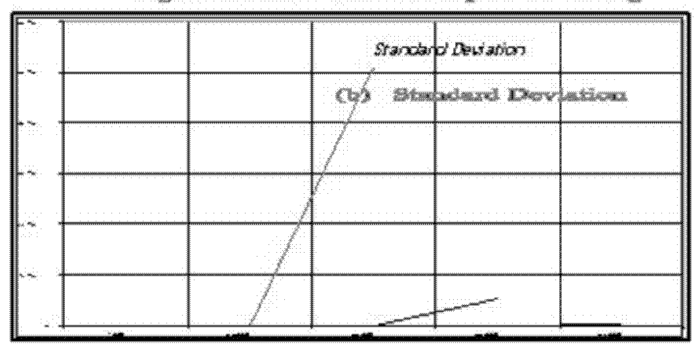


Fig. 12 - 11: The Results of capacitive loading



12 – 3: STATISTICAL PROFILE

The process of profiling for a group of data may be expressed mathematically either through a deterministic or by a stochastic concept. The deterministic style is a mathematical model, which means the actual specified all data are included in the system while the stochastic concept gives an overall view for the system through either all data or some random values.

Although this last concept may introduce an error according to the statistical principles, a good result expressing a problem can be easy achieved. This will be more difficult with the internal transients.

Therefore, the above analysis can be used to get a general profile for the processes of switching transients in a certain specified network.

Any network contains different numbers of distribution and transmission systems. There is a specified ratio of these systems at a certain moment but this ratio will be varied with each extension, which must be normally happened, continuously, at least in the distribution system. So, the ratio between both systems inside the network will be actually a dynamic ratio. Therefore, a general profile for such specified network at a certain moment can solve the problem of generalization of the view for this network. Thus, the distribution to transmission ratio (DTR) my be defined by

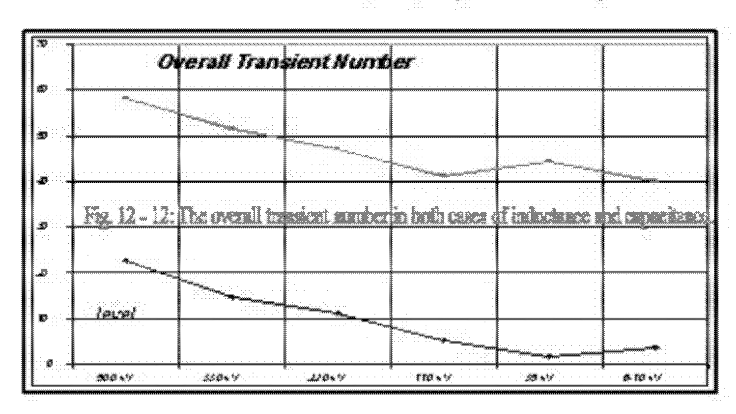


Fig. 12 - 12: The overall transient number in both cases of inductance and capacitance

Table 12 -8: The proposed value for the percentage content of transmission and distribution systems (Z in p. u. system)

Case / Parameter	Z	Base	1st	2nd	3rd	4th	5th
500 kV	13.2	30	30	30	30	30	40
220 kV	7.2	50	50	50	50	40	40
110 kV	4.8	20	20	20	20	30	20
$(N)_T$		21.3	21.3	21.3	21.3	20.7	23
35 kV	2.8	30	10	10	10	10	10
11 kV	1.0	50	60	50	40	40	40
6 kV	1.36	20	30	40	60	60	60
$(N)_D$		10.15	12.4	15.55	22.1	22.1	22.1

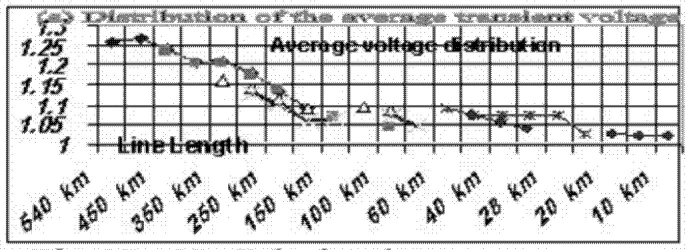
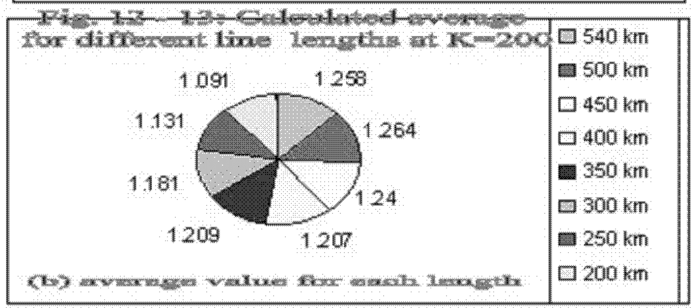


Fig. 12 - 13: Calculated average for different line lengths at K=200



$$(DTR) = \Sigma (Z_l)_D \;/\; \Sigma (Z_l)_T \qquad (12\text{-}17)$$

Consequentially, line impedance can be computed according to the specific resistance and inductance multiplied by the length and then, the summation of impedance for either transmission or distribution would be evaluated. After that, a defined profile for a network should be deduced for at a certain network at a specified time but a general profile for this network may be evaluated at all values of (DTR).

On the other hand, a general ratio (GR) may be proposed as:

$$(GR) = DTR \,/\, (1 + DTR) \qquad (12\text{-}18)$$

This will be useful to find the general profile for a network through the general transient number by:

$$TN_G = (GR)[(N_t)_D - (N_t)_T]/K + (N_t)_T/K \qquad (12\text{-}19)$$

This general transient number may be evaluated for system specified, but it may be important to find its change due to the growing in the electric systems as a whole. So, a basic configuration for a power system is suggested as listed in Table 12 - 8 where both transmission and distribution systems re indicated according to the self parameter for each voltage level. Then, different cases with the variation of such power system are considered on the bases of normal growth in the developing counties. The impedance is referred to the 11 kV impedance as calculated statistically above while the percentage content for either the transmission (500, 220, 110 kV) or the distribution (35, 11, 6 kV) level with the determined transient number. Therefore, the constant configuration for the transmission system is considered (basic case), where the variation is applied to the distribution level.

The general transient number is computed for each case as shown in Fig 12 - 16. Also, the change in the transmission system is given (cases 4 and 5). It is shown that the transient content in a network will be increased with the growing in the distribution network. This may give more increase with the great extension in the lower level of

voltage so that a corresponding extension will be needed as proved for the case 4, where the 110 kV increased.
It should be indicated that this extension balance cannot be achieved t the highest UHV scale (case 5). Tables 12 – 9 and 12 – 10 presents the final results for the cases of study above.
Thus, the proposed technique will be useful for the planning and design of power systems in general and for electric station specially in order to decrease the transient level inside a network. This may be clarified with the rate of rise of the transient content as given in Fig. 12 – 17 for the studied cases referring to the basic one. The rate of rise is increased with 6 kV (35 %) although it reaches 40 % for the UHV extension. This proves that the proposed concept for the general transient number must be considered for any extension to avoid the heavy presence of transients in a power system.

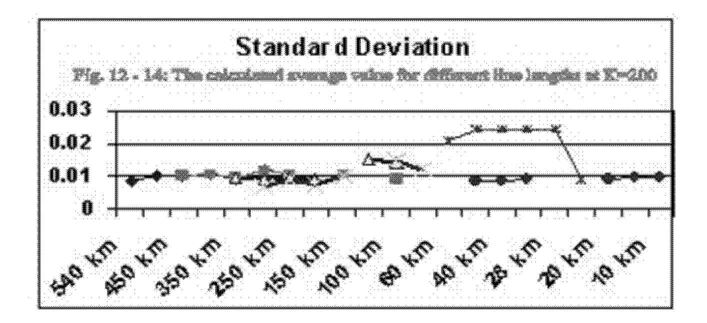


Fig. 12 - 14: The calculated average value for different line lengths at K=2.00

Finally, the proposed simplified concept for the evaluation of transients in both transmission and distribution systems through the transformation into the so called the wave mode coordinates. Also, it is valid for both transposed and non-transposed phases. This value would be an importan6t factor for the selection of the circuit breaker type and capacity in the design procedure.
The use of bulk capacitors in the single line diagram for the designed station can be treated as the distribution power network according to the presented results for the transient presence in a percentage style.

Also, with the limits of resonance phenomena may be derived simply. The overall transient number for the power stations or network in a statistical base has been realized so that the UHV and EHV still have the heavier transient presence.

Table 12 -9: The deduced profile for the proposed cases of transmission and distribution systems in the selected network

DTR \ Case	Base	1st	2nd	3rd	4th	5th
DTR=0.3	19.724	19.144	19.972	21.485	21.623	22.79
DTR=0.4	18.111	18.755	19.656	21.529	21.1	22.74
DTR=0.5	17.583	18.33	19.38	21.566	21.17	22.7
DTR=0.6	17.119	17.962	19.144	21.6	21.225	22.66
DTR=0.7	16.717	17.642	18.94	21.629	21.275	22.6
DTR=0.8	16.349	17.348	18.747	21.655	21.322	22.6
DTR=0.9	16.015	17.081	18.575	21.68	21.364	22.57

It should be mentioned now that the evaluated mathematically rate of rise of the transient content, referring to the base case for the proposed cases of transmission and distribution systems in the percentage system (%), in order to reach a relative comparison between all cases. This may be tabulated in Table 12 – 10.

Table 12 -10: The calculated rate of rise of the transient content, (%)

DTR \ Case	1st	2nd	3rd	4th	5th
0.3	2.24	6.664	14.746	12.28	21.72
0.4	3.556	8.53	18.87	16.51	25.57
0.5	4.25	10.24	22.655	20.381	29.1
0.6	4.924	11.83	26.176	23.99	32.38
0.7	5.533	13.28	29.382	27.27	35.37
0.8	6.111	14.67	32.46	30.415	38.23
0.9	6.656	15.982	35.368	33.397	40.95

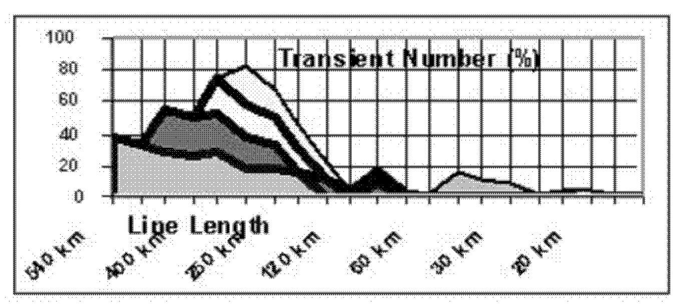


Fig. 12 - 15: The derived transient number for different line lengths at K=200

The statistical profile is a good tool for the planning and design of electric stations or power systems specially with the quick developing networks. This case may be appeared in the developing countries where the great density of population will be presented.

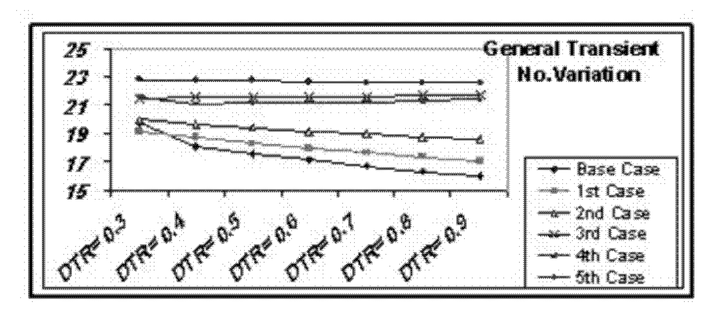


Fig. 12 - 16 : The deduced profile for transmission and distribution systems

Finally, it should be mentioned that the given analysis gives a view for the methods required for the calculations of a transient level or as it is known as the insulation coordination in a power system between stations and connectors. This title represents one of the major items required for the design of a station or a transmission line. On the other hand, electro-dynamic transients can guarantee the reliability of operation of a network because this transient stability is a very important factor for the validity of a station to operate in a power network. Transients in general are a major part of the complete study and design of a station so that it may be one of the main steps in the procedure of calculations during the design process.

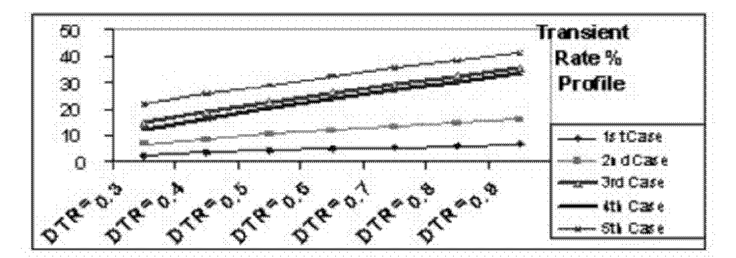


Fig. 12 - 17: Rate of rise of the transient content, referring to the base case for transmission and distribution systems (%)

Chapter XIII

RENEWAL ENERGY

Energy can be considered as the most important research title in the 21st Century because the petroleum oil reserve quantities are going to a decreased limit. It is a world ring for the approach from a red line in this field. This problem must be faced and treated well for the human on Glob - as well as energy is a vital source for human life on earth.

Researchers in the energy and earth sciences take also an atomic-level look at our world. For those in the energy sciences, the targets are the physical properties and chemical processes behind the production and consumption of energy. In the earth sciences, researchers are studying the environment above and below our planet's surface. It is important to mention that the term "energy research" and the image most likely to be conjured is that of massive power plants or sprawling factories. Although the new energy technology does investigate ways of improving the efficiency and reducing the pollution of such plants, its scientists are also conducting research into areas less dramatic but no less important. For example, the act of switching on a light can be considered for the indication to power consumption.

American taxpayers annually spend an estimated $ 30 billion in energy costs for electrical lighting--including residential, commercial, industrial and street lighting, plus lighting for miscellaneous purposes such as stadium events (according to the registered load curve practically). This accounts for about 25 % of the electrical energy consumed in the U. S. A. each year. The same annual percentage approximately may be lost in each country for lighting so that a new creative concept for lighting may lead to a great saving in the traditional fuel used.

Scientists believe that this consumption could be reduced to the half if existing lighting systems were replaced with a new energy-efficient illumination style. To this end, they have been working with industry

to improve the illumination and energy-efficiency of fluorescent bulbs (and also other types of lamps) as a marketable replacement for energy-wasting incandescent bulbs. However, saw the unveiling of an even newer technology that has the potential to rewrite the future course of electrical lighting. Scientists call this promising new technology as *molecular emitter lamp* **but it will probably come to be known to consumers as the "sulfur lamp". This represents one of the actions done beside new planned for future.**

Four times more energy efficient and 700 times brighter than a conventional incandescent bulb, the sulfur lamp also outperforms the best of the new fluorescent bulbs. It is known that the first lamp, produced in conjunction with Fusion Lighting Inc. of Rockville, Maryland (USA), consisted of a glass globe the size of a golf ball that was filled with argon gas and a tiny amount of non-toxic sulfur, rather than the toxic mercury gas used in fluorescent tubes. It is a friendly acting with environment.

On the other hand, microwaves were used to electrically charge the argon gas which in turn heated the sulfur and made it glow, giving off a rich bright light that described to having a miniature sun in the room. This is done to raise the efficiency of light intensity in order to save the power consumption. A prototype version of the lamp is now on public display in Washington D. C. at both the U. S. Department of Energy's headquarters and at the Smithsonian Institution's National Air and Space Museum. This is a way to save the traditional fuel in a country.

13 - 1: SOLAR STATIONS

Nowadays, the international energy problem becomes the most vital one on the glob because this energy is easy for a country and hard for others. This item may has a raised level of importance due to the political situation in the new world. Also, the unstable market of petroleum may be a political dependent market since some counties have it and buy to others. This leads some countries to concentrate on the requirements in order to modify and improve the present world condition from the point of view of energy consumption.

Equally important to international energy conservation efforts are

energy-efficient windows in the world. For example in USA each year, the amount of money required to offset the heat lost in the winter and gained in the summer through windows costs American taxpayers about $ 25 billion--a loss comparable, in terms of energy, to the amount of oil delivered through the Alaska pipeline. It is annual loss in energy of traditional fuel mostly. Scientists, through such projects as "super windows" for example where new and improved "smart windows," have been transforming windows from an energy liability to an energy asset. This problem faces all countries of the world due to the continuous reduction in the reserve oil. Researches should be concentrated and directly for the new types of power stations where the reserved oil would be reduced by time.

In addition to research on lights and windows, scientists in the world also develop computer models that simulate all aspects of energy consumption inside buildings. It has been determined that Americans for example spend more than 80 % of their time indoors and that more than $ 200 billion of this country's yearly energy bill is spent on meeting indoor energy needs, the potential for savings is substantial. Thus, the saving of energy is a target for all persons on the Glob. A new tendency for the style of consumption of energy, specially that lost in meeting as well as other similar utilizations although out door style meeting may be a new concept for the reduction of the used energy.

Recently, energy researchers released new most successful simulation programs. It is a tool to help engineers and architects for the reduction of energy consumption in the buildings they design. This will minimize the loss of loads besides the transmission loss as explained before. The new programs can calculate the hourly energy use and its costs of any type of the commercial or the residential building annually based on such information as the dimensions, construction materials, geographic location and orientation of the building, plus local weather data. If the local utility rates are given, the program will calculate the building's annual energy bill. The energy-efficiency of alternative building designs can be compared and optimized long before any concrete is poured.

On the other side, energy researchers have not ignored the larger problem of factory waste and pollution as a title of environment.

The scientists who developed a cost-effective technology for clearing the air of sulfur dioxide pollution from power and chemical plants have now taken a big step towards clearing the water of future pollution from pulp and paper mills. They developed a chemical process called "POZONE" that cuts in half the cost of producing ozone. By putting ozone, which is a molecular form of oxygen that can serve as an environmentally benign bleach, on a cost-competitive footing with chlorine, the POZONE process will help paper manufacturers meet proposed new standards.

This may raise a certain amount of load away from the station, generating the power. In the past, ozone-bleaching has been considered too costly because the production of ozone involved an expensive electricity-based process. POZONE produces ozone through the inexpensive chemical reaction of yellow phosphorus with oxygen. The potential for POZONE extends well beyond the pulp industry, because the technique can also be used to recycle carbon that has been used by a large number of different industries to adsorb toxic solvents. This contaminated carbon has traditionally been buried, which means it can pose a threat to groundwater.

Otherwise, the new concepts need a great funding as well as the hard effort in order to reach the target. This is useful for any person in each country so that researches for a reduction use of traditional fuel may be the first important target for the world. Then, a creation for a new style of fuel or a new application instead the use of traditional fuel either through direct or indirect use may be a world aim. However, this tendency can be achieved by rationalization of its implementation. It has many ways for the reduction of energy utilization.

In spite of removing buried toxic wastes that have been found to be contaminating groundwater has always been difficult, assessing the risk posed by these underground sites has proved troublesome. Artificial and natural pools tasks require the drilling of holes into soil that is of such poor quality (which is why it was chosen as a burial site for waste). It often crumbles and clogs up the hole. Conventional drilling mud used to stabilize commercial bore holes can't be used for fear of spreading contaminants even further.

Earth scientists may have found a solution with the development of a drill that blasts super-cold nitrogen gas as it bores, creating frozen holes that won't collapse even in the most difficult of soils. In this technique, which is called "cryogenic drilling," nitrogen is injected down the drill's center pipe and exits through nozzles near the spinning drill bit. At 196 degrees-below-zero Celsius, the gas freezes difficult soils rich in sand, gravel or ash long enough for workers to insert stabilizing metal casings into the holes before the ground thaws. Thus, reflected subjects may vary in a wide range so that a new concept for energy generation may be required. These above items could be the next type of energy generation although it may cost more and expensive today.

Similarly, the power station may either utilize the water difference between both sides of a dam (as the case of hydro power stations) or use a fuel as thermal power stations (gas or cook or oil fuels). Therefore, nuclear power stations may be classified within the types of power station with all the above stations while all of them pollute the environment as well as the fuel costing. Consequently, a new fuel such as a solar type of power stations may save these types. Then, this concept will generate a pure environment as well as it reduces the use of traditional fuel in other types of power stations. This may be explained in the present chapter in order to put shortly some of the various theories for the generation of energy or even creating it. These stations may be called as sun energy stations.

1 - Solar Pond

A typical solar pond has three regions - as it is seen in Fig. 13 – 1 – where these three layers are indicated inside a vessel. This pond may be explained shortly with a tailored title in the next paragraphs while it is not representing the only method for energy generation. There are a lot of concepts and applications to generate energy but the economic application still high expensive till now. It is a renewal energy source because it has a renewal characteristic. It is a self generated type of energy.

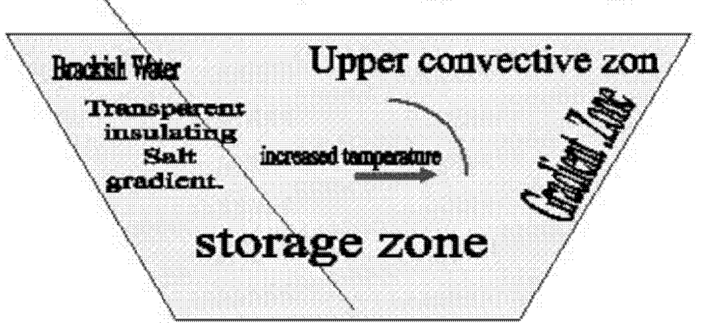
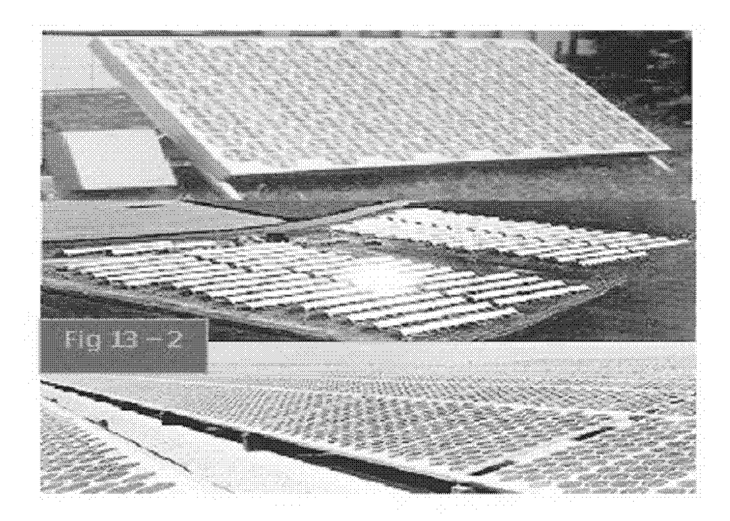


Fig. 13 - 1 : Typical Solar Salting

However, the top region is called as either the surface zone, or upper convective zone while the middle region is known as the gradient zone, or in another name as non-conductive zone. Finally, the lower region is entitled as the storage zone or sometimes it is called as the lower convective zone. It may be the future power stations as the generated power must be connected to the network. The solar pond is one of the simplest devices for direct conversion of solar energy into thermal energy. Moreover, it is simultaneously a collector of solar radiation and a thermal storage device. the artificial solar pond prevents either vertical convection or surface evaporation and convection or both.

The lower zone (Fig. 13 - 1) is a homogeneous, concentrated salt solution that can be either convective or temperature stratified. The convective gradient zone constitutes a thermally insulating layer that contains a salinity gradient. This means that the water closer to the surface is always at less concentrated salt than the water below it. The surface zone is a homogeneous layer of low-salinity brine or fresh water. If the salinity gradient is large enough, there is no

convection in the gradient zone even when heat is absorbed in the lower zone, because the hotter, saltier water at the bottom of the gradient remains denser than the colder, less salty water above it.
Because water is transparent to visible light but opaque to infrared radiation, the energy in the form of sunlight that reaches the lower zone and is absorbed there can escape only via conduction. The thermal conductivity of water is moderately low, and if the gradient zone has substantial thickness, heat escapes upward from the lower zone very slowly. This makes the solar pond as both as a thermal collector and a long-term storage device.


Fig 13 – 2

However, non convicting ponds usually prevent heat loss by inhibiting thermal buoyancy convection. It may be mentioned that, naturally ponds isolation is converted into heat within the pond, but the warmed water from the bottom rises to the surface. During this process most of the heat is lost to the atmosphere. Non-convective ponds employ a salt gradient to prevent the warmed water from rising to the surface where the salt concentration in such ponds is highest near the bottom and lowest near the surface.

As a solar radiation enters the pond – whatever, it is not absorbed in - the water is absorbed on the dark bottom.

2- Salt Concentration

Consequentially, the heat must be collected and then concentrated at the bottom of the vessel and then, deeper waters warm up according to the density factor effect. However, the increased density created by the salt prevents this thermal buoyancy convection. Heat transfer to the pond surface primarily by conduction. Vertical convection takes place in the top layer due to the effects of wind and evaporation. This layer serves no useful purpose and is kept as thin as possible. The next layer, which may be approximately 1 m thickness, has a salt concentration that increases with depth; this layer is known as the non-convective zone. This heat excess accumulation is generated from the sun supply of energy (zero cost supply).

The bottom layer, which is convective (constant slat concentration), is a concentration zone. The cost of salt for a solar pond represents a sizable fraction of the total initial investment.

A suitable salt has several criteria as:

i- It must be adequately soluble with a solubility that increases with temperature.
ii- Its solution must be adequately transparent to the solar radiation.
iii- It must be environmentally safe.

3- Solar pond applications

Solar ponds are readily applicable for such low-temperature implementations since it can be considered as residential or commercial heat. They can be used for either cooling systems or electric power generation. This indicates that the pool generation stations may come later as the bulk generating hydro power stations or even nuclear stations. Solar stations are in the way to the field of electric power systems if the installation cost becomes cheaper.

4- Photovoltaic Stations

This is a more spread technology for the utilization of the sun supply energy source so that its type may be introduced soon in the electric power network. It depends on the photo cells technology as it is seen in Fig. 13 -2. Different types of photo cells are seen in Fig. 13 -2 where all of them are in use in different applications around the world. These cells collect and concentrate the sun heat energy in order to convert it into an electric supply power. It must be noted that these cells are very heavy due to the hug number used in a station.

Fig 13 – 3

This may need a support system of steel or galvanized iron in a large dimensions where it takes the form of portal and towers of a transmission line. This support has been given in Fig 13 – 3 where the solar cells are supported above. Also, the system as a whole can be applicable and it represents a success method for the generation of electric power specially in the far sites or places. It is also the first shape of help in cosmic applications.

This sorts the given station as the Untraditional Sources of Electricity or the renewal sources of energy because these sources are a nature power without the influence of human. Here, the non traditional means the non ordinary type that we use. So, the renewal energy sources as solar energy (See Fig. 13 -2) could inserted inside

but a new proposal could be remarked in this point. Also, this cell as a group needs to a steel foundation as shown in Fig. 13 -3. It is heavy and cost for the stations of solar energy generation.

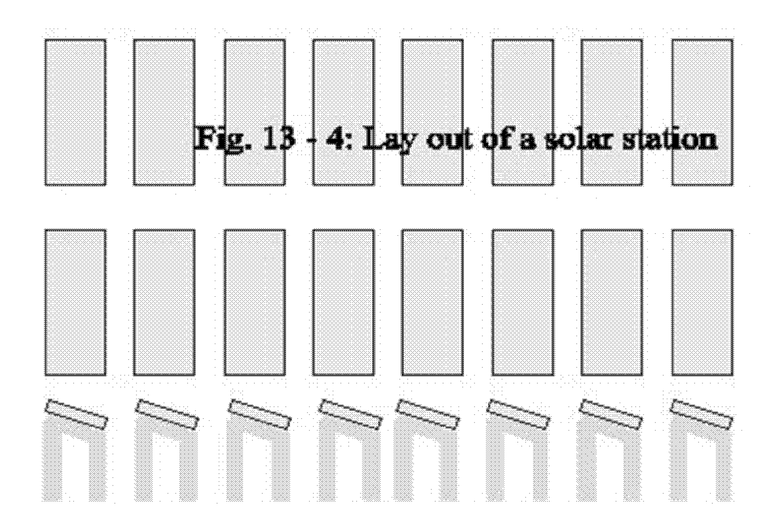
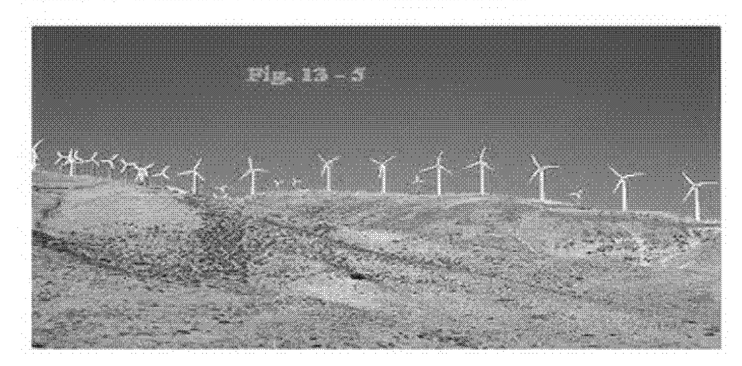


Fig. 13 - 4: Lay out of a solar station

However, the Electrolysis in these stations in the field of renewal energy scale may include some sub-titles to work under a certain rule. This may be mentioned as a Photo Strategy in the few next lines. In this process solar panels absorb sunlight and converts it into an electric current directly for use in the electrolysis reaction. It is a costing concept. Currently the cost of efficient solar panels is astronomical, therefore not very practical. Currently there are numerous studies as to the feasibility of photo-electrolysis. Numerous institutions are investigating the possible materials that can lower the cost for the solar panels to be used in this process.

Contrary, Hydro Technology may lead to a main disadvantage where Hydro Electrolysis entails using hydroelectric power plants to fuel the electrolysis process. It does not as widespread as the above-

mentioned processes. Currently Hydroelectric power plants are few and far between because the number of water falls is small. It depends on the nature before any other factors.
It should be noted that solar stations in small scales are a good economic for space applications as well as for far locations in desert or hills. Also, it is a good way for the power generation for lights on high ways and for communication stations in general. It is also, a good tool for advertising in far as well as for near places. Contrary it has a main disadvantage which can be concluded in the output type of current because it generates a DC type of power. When it is later becomes a large power solar stations, it will be needed to be connected to the electric power network. Then, the connection of solar DC station to an AC electric network will be expensive due to the required converting station between AC and DC systems.
The lay out for a solar station may be given in Fig. 13 - 4 where similar grouping for larger power can be drawn. Also, it should be said that theses stations may have too a control room in order to check the angle of the cells towards the sun. These stations need a sunny weather for a long time such as middle east.


Fig. 13 - 5

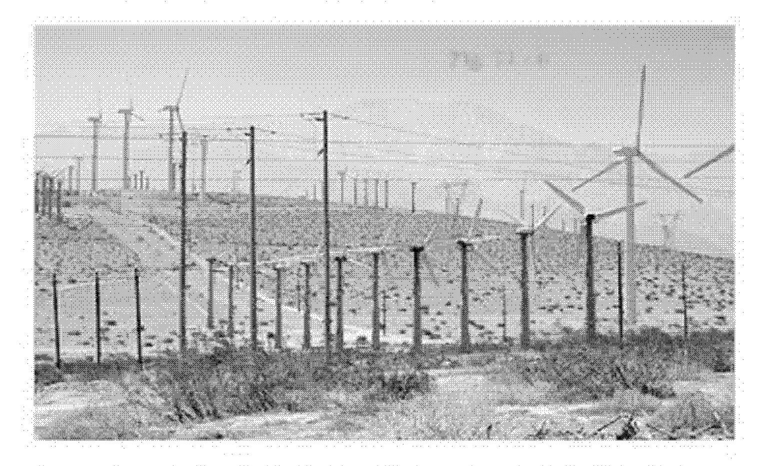
13 - 2: WIND STATIONS

The nature gives us the solar energy as well as a lot of others so that many and many of artificial sources of energy can be replaced by the nature powers. The renewal energy is one of the nature

characteristics that help human in his life. Although storms is one of the forms of natural disasters, they must be controlled and treated in order to overcome their disadvantages. Storms as a source of energy needs also, a great attention in order to convert the disaster performance into a useful energy. The useful part of storms such as winds can be normally utilized for the generation of energy. Wind has no cost for use but the mechanism required to convert into electric energy costs. Wind can not be applied on any place on the earth but it must be used where a generation mechanism may be installed. This is a weather performance on the earth either by time variation or place on it.

1- History

Wind-generated electricity is simply a new application for an old idea. It is similar to that energy of wind when it was used for the mailing of boats in Niles as Pharaoh in Ancient Egypt and then over seas. Scientists in the world have been hardly work with wind from the beginning so that history may prove it.



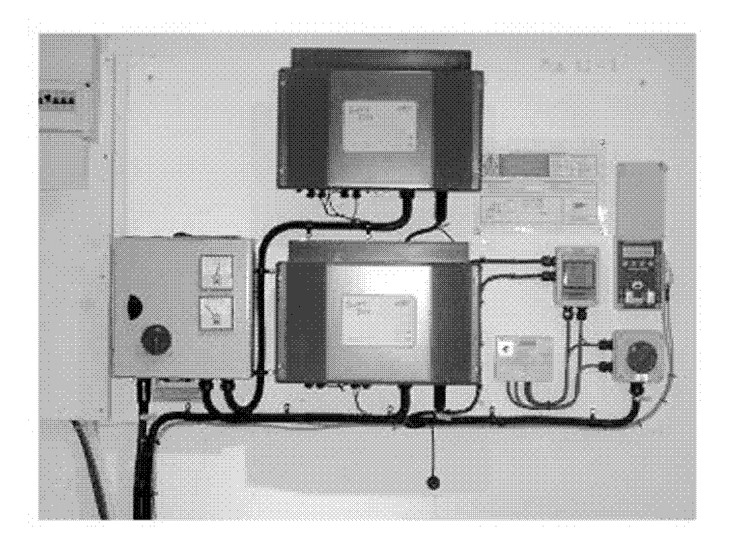
According to the U.S. Dept. of Energy's (DOE) Wind Energy Program website, wind power has been used since earliest recorded

history. There is evidence that wind energy was used to propel boats along the Nile River as early as 5000 B. C. Several centuries before Christ, simple windmills were used in China to pump water.
In more modern times in the United States, windmills were erected as the West was developed during the late 19th century. Most windmills were used to pump water for farms and ranches. By 1900 small electric wind systems were developed in USA to generate direct current, but most of these units fell out of favor when rural areas became attached to the national electricity grid during the 1930s. By 1910, wind turbine generators were producing electricity in many European countries.
Recently, a wind power has become an appealing alternative to fossil-based fuels, especially in countries with scarce petroleum and ample wind. According to the Danish Wind Turbine Manufacturers Association, there were 1,129 MW of installed wind capacity spread out over 4784 turbines in Denmark in 1997.


Fig. 13 – 7

This technology has a potential for further use in the U. S. A. The official site on the WEB contains a map of annual average wind speeds throughout the fifty states of U S A. Areas with the highest average amount of wind (such as mountain ridges and coastal areas) would produce the most electricity. Accordingly, "North Dakota, alone, has enough energy from ... winds to supply about 36 % of the

electricity of the lower 48 states in USA". This may be a clear wind map for any required new design area such in Egypt now. For example, such wind farms are installed and work well with a good performance where it is placed at ELZAHFARANA on the coast of red sea. Thus, the investment in the field of energy generation by wind can be easily proceed. It is important to put advantages and disadvantages of the wind power generation as follows.



However, for example the Wind Turbine System, at the Campus Center for Appropriate Technology, is simple, as the mechanical mechanism in general may be the most important part, while the fans or the turbines can be taken as the general view as given in Fig. 13 - 5. These fans are spread on a very large area of the land so that it is normally called as the wind farms. On the other side, these fans are high as possible in order to get the highest possible speed of wing. Also, these fans can be called wind wheels. These wind stations consist of a lot of elements so that the wheels are the simplest part in them. Then, these stations may be very necessary for applications in spite of their high cost relative to the equivalent thermal stations.

The turbine is mounted on a 26 m tower to clear nearby trees.
However, a good view for a Wind -Turbine-Generators - farm has been given in Fig. 13 - 6 where the great collection for the fans inside a certain area of the farm is mentioned. Then, it may be necessary to determine that these wind farms are usually built on the face to wind directions so that it may be installed at the hills or on mountains as shown in Fig. 13 – 5 and Fig. 13 – 6. Consequently, theses farms can be installed too on the way of water winds where the wind has always a high speed as given in Fig. 13 – 7 where the fans are built on the water. Total height of the wind generators (tower and blades) at wind farm is 328 ft.


Fig. 13 – 9

It must be noted that stress on renewal energy application is always increasing and more concentrated so that a deep view now may be fulfilled. In addition to solar power and a back-up generator, Humboldt State University's CCAT (Campus Center for Appropriate Technology), for example, uses a special type of turbines such as Whisper H500 wind turbine system in order to meet its energy needs. Also, a brief history about wind energy may be required for remember. Then, the usual Installed electrical panel may be given for the purpose of illustration in Fig. 13 – 8. It is equivalent to the control room of a station as explained before and it can be titled as control room. This is the electrical panel where the turbine output is connected to the grid and the customer; the two red boxes are 2.5 kW inverters. There are also, disconnecting switches and a meter for recording turbine output. The meter readings are used for the connection between generators and the various loads on the BB. The inverter output would be necessary in order to feed into

the consumer unit, which can be seen top left.

2- Advantages of wind energy

The source of electricity for this process is, quite simply, wind while it will be harnessed through the use of windmills (Fig. 13 – 9) or fans (Fig. 13 –10) and power generators. The windmills will power the generators that may then fuel the electrolysis process. Scientists are trying to cover each point in the subject. It has been determined that zero emission wind turbine does not produce any greenhouse gases as well as it does not cause a pollution, such as Carbon Dioxide, Nitric Oxides or Methane. As a result, it has less overall environmental impact than if it were to rely on fossil fuels and nuclear power.

i- The space (area), which wind farms occupy, can still be used for agriculture, grazing, ranching or most other uses before the turbines were installed. Turbines can be mounted on the top of buildings.

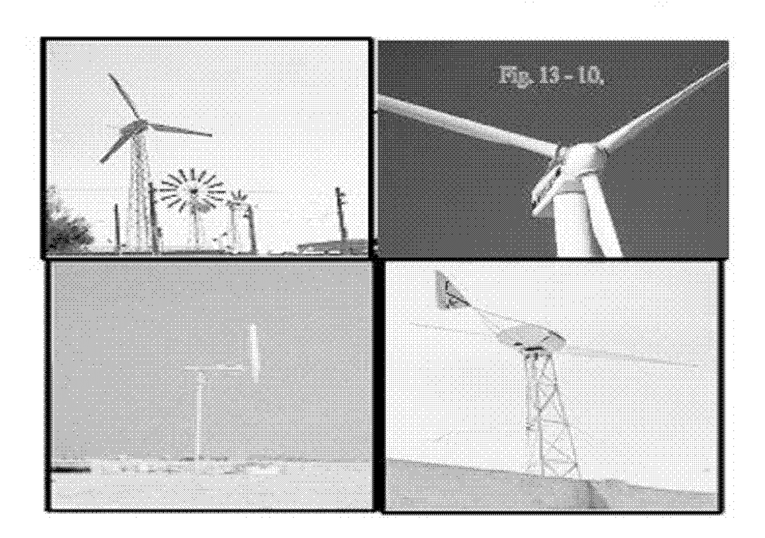


Fig. 13 - 10.

ii- Financially, turbines pay for themselves quicker than most other types of energy production. If one invests $ 10,000 in a family-size wind turbine system (tower, inverter, turbine, accessories, etc.), and the turbine produces $ 1000 of electricity savings per year, the system pays for itself in ten years.
iii- Maintenance is minimal where monthly maintenance consists of visual inspections of the mechanical condition of a turbine, inspecting the tower, and testing the brake. Annual maintenance consists of battery inspections and an up close inspection of the turbine.
It should be marked here that the wheeling fans have many different shapes as given in Fig. 13 -10. They are either single or double or triple or multi blade fan type. These shapes may be a factor in the design of a station.

3- Disadvantages of wind energy

Disadvantages for the wind plant in a brief items can be treated as follows:

i- Avian (bird) mortality is being studied currently to determine if industrial wind turbine farms contribute to the demise of large birds of prey such as golden and bald eagles. Preliminary results indicate that avian mortality is specific to the site (if it's on a flyway), not the turbines in general.
ii- Noise may also be a concern, especially with large turbine blades that are close to the ground.
iii- traditional radar system may be influenced due to the storming characteristics in the zone.
iv- The variable value of generation with time and seasons.

4 - Control Box

Although solar sun generation depends on the heat energy conversions through electric wiring, the wind generation depends on the mechanical energy from wind through a mechanism (Fig. 13 -11). This can be done by the control box (Fig. 13 -11) which performs the function of distributing the power produced by the wind turbine. In the upper left-hand corner of the box is a digital display.

This displays the Volts per cell, Volts per battery, Amps per battery, Amps from the wind, Amps from Photovoltaic cells, or Amps Load, depending on where the adjacent switch is set. In the upper center is a guide to how fully charged the batteries are. The upper right hand corner of the box has a switch that sets the voltage at which the batteries are charged.

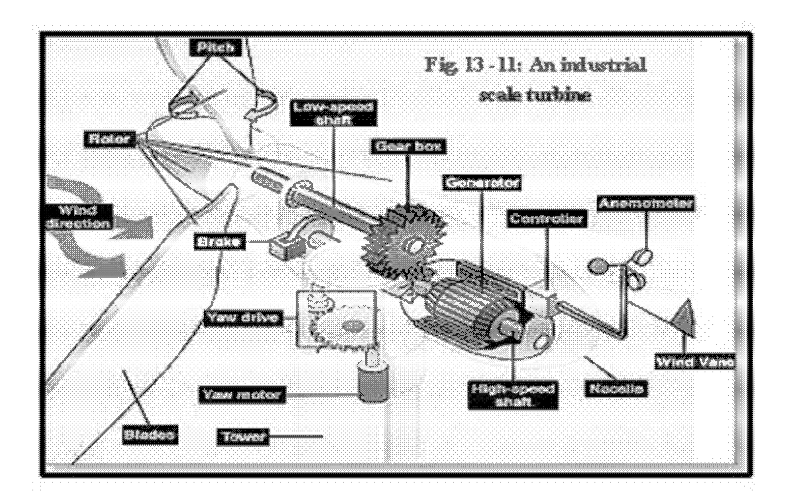


Fig. 13 - 11: An industrial scale turbine

On the right hand side of the control box is a load that will dispose of excess electricity by heating a coil. The bottom right of the control box contains switches that will control whether the load for the house is on or not and whether solar power is on. There is an additional switch for braking the turbine in the lower center.

5 - Kinetic energy of wind

Aiming to present a brief but possibly integral design procedure for the wind Mills (WM), the main physical relations describing a WM operation will be presented. Wind is a moving air having a mass (m ρ) which depends on air pressure, temperature, air contents and

pollution. Since it is a moving mass, it has an inherent kinetic energy Wρ which may be described as (Fig. 13 -12):

$$W\rho = 1/2\ m\rho\ v_o^2 \qquad (13 - 1)$$

Where v is the speed in m/s of the moving mass in kg. so the obtained energy will be in kg m s (i.e. Nm. Joule) or (Watts).

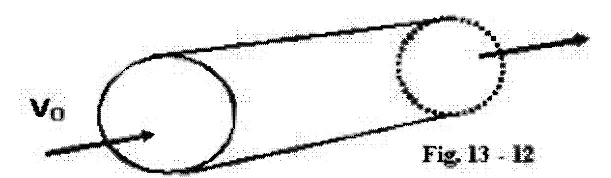


Fig. 13 - 12

Considering that the movement of the air mass represents its kinetic energy, the resulting power can be represented by the air mass passing through a given area in one second. Assuming the air mass per time unit is mρ, the density ρ and speed v through the cross section A it results:

$$m\ \rho = A\rho\ \ v_o \qquad (13 - 2)$$

As the air mass m passing through across section A, the inherent power P becomes to be:

$$P = W\rho = 1/2\ m\ \rho\ v_o^2 = (1/2)\ A\ \rho\ v_o^3 \qquad (13 - 3)$$

Table 13 - 1: presents air composition for dry clean air

Gas Type	Nitrogen (N2)	Oxygen (O2)	Argon (Ar)	Carbon Di-oxid (CO2)
Volume Content (%)	78.09	20.95	0.93	0.03
Mass Content (%)	75.52	23.15	1.28	0.05

The air density depends on air composition and pollutants, on air pressure and on temperature (Table 13 - 1). Its value at sea level and a respective rated pressure of 1013.2 mb and 273 k for clean and dry air will be 1.292 Kg m^3. The air composition is nearly constant throughout a layer of the height of 11 km above the sea level due to the strong mixing process in the troposphere.
The inherent kinetic energy in moving wind into mechanical energy, wind energy converters (WEC), which are devices capable of transforming appears on the rotor axis of the wind energy converters. The two existing categories of wind energy converters are characterized by the principle of transformation of wind energy such as lift type wind energy converters and Drag type wind energy converters. It is needed to focus briefly on factors influencing the real obtainable power from the wind stations. It can indicated due to the performance of generation as:

i- The angle of inclination of the blades measured to plan of rotation is a decisive factor determining the power coefficient of the WM and hence the effectiveness of the blades to convert the kinetic energy of the wind.
ii- The effective velocity Ve is the geometric sum of the mean wind speed

$$V_e = (v_o + v_a) / 2 \qquad (13\text{-}4)$$

and the relative motion of the blade foil. This results a lift force Fl acting on the blade foil described by the formula:

$$F_1 = C_1 \rho V_e^2 A_1 / 2 \qquad (13\text{-}5)$$

Where Cl is the lifting coefficient, ρ the air density, and Al the area exposed to the lift force at the same time a drag force Fd is acting on the blade profile which can be described by:

$$F_d = C_d \rho V_e^2 A_d / 2 \qquad (13\text{-}6)$$

Where Cd is the drag coefficient and Ad the area exposed to the drag force. It is mainly opposing the movement of the blade.

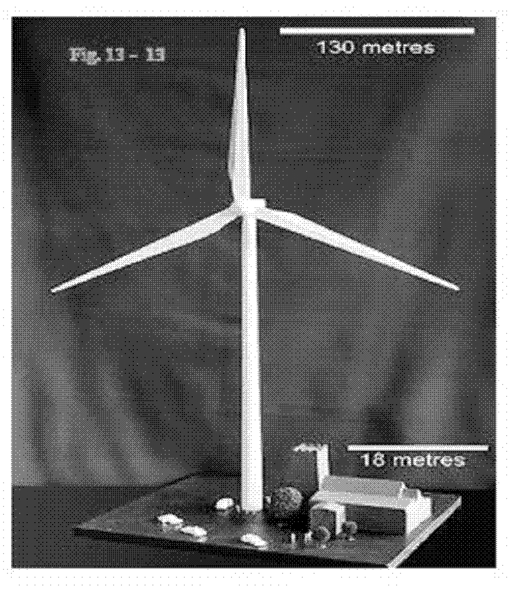


Fig. 13 - 13

6– Lay out of wind stations

It should be noted that the dimensions of a fan is very large as well as its supporting tower as shown in Fig. 13 - 13.

The main factor here is the location of the wind farm where it

represents a wide area and space in the three coordinates. This figure shows also, the control room for such stations where it is a small room containing all connection to get the output power of all fans in the site. Also, the electrical connections may be installed inside as well as the general lay out for a wind station may be seen in Fig. 13 – 14.

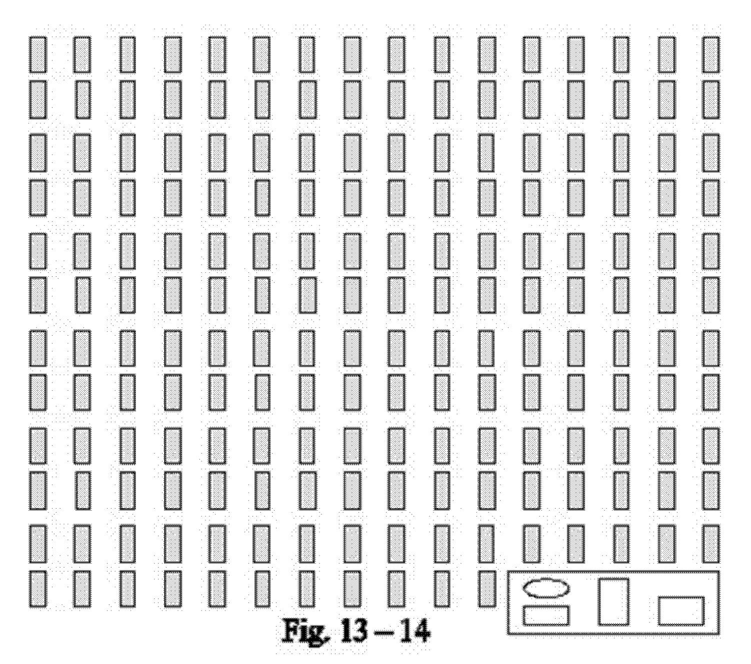


Fig. 13 – 14

The elevation of a unit tower may be illustrated as in Fig. 13 – 13 where the picture can be considered as an elevation view. The blades are shown with the head of the tower. Contrary, the line of allocation of each row of the fans may not be a straight line where it is configured according to the geographic potential. It can be a circular line or a broken line according to the case. This may vary in the 3 – D Cartesian coordinates due to the found mountains or hills

or even inside a watered land. This would be reflected into the lay out of a station.
Whatever, there are many special types of windmills that correspond to the weather and installation characteristics as well as a 30 m turbine for example with a special shape has been given in Fig. 13 – 15. Another special shape of turbines which is known as H-Darrieus-turbine is also, given in Fig. 13 – 16. It is seen from Fig. 13 – 15 and Fig, 13 – 16 that the tower of the fans is very high while it needs a good tie and fixation on the land. This is important because the wind effect on the body of the tower itself is high. The pictures say more.

13 - 3: VARIABLE DEMAND STATIONS

The function of a power station is to deliver a continuous power to a large number of consumers at everywhere. However, the power demands of different consumers vary in accordance with their activities and types so that the load on a power station is never constant, rather it varies from time to time. Most of the complexities of modern power plant operation arise from the inherent variability of the load demanded by the users. Unfortunately, electrical power cannot be stored and, therefore, the power station must produce a power as and when demanded to meet the requirements of the consumers. Then, the power engineer would like that the alternators in the power station should run at their rated capacity for maximum efficiency with the wide varied demands. This makes the design of a power station highly complex because a constant demand generation may help in the reliability action during the steady state operation.
The suitable load for a certain generation is an ideal case but with the varied demand generation the problem becomes dummy. So, The demand power can be classified into either installed demand and generation demand. This means that the generation demand in all types of stations (thermal, hydro, nuclear, renewal) is usually less the installed demand. On the other hand, This condition will be more worst because the actual real time generated demand in renewal energy stations is always variable in a wide range plus it is less than the installed value. Therefore, a power station is designed to meet the load requirements of the consumers with a difficult construction if it

is a thermal type. It is seen as given in the previous chapter of the present book that, a harmony style in the arrangement of units as well as a similar distribution for the tanks (Containers) of fuel.

A constant load for a long duration may be defined as ideal load on a station if the duration is 24 hours daily and the load value is the station demand. This is not a practical condition due to the nature of use of loads according to the performance of load curves. This load may be semi ideal if one of the two variables is fixed as the duration of the loading approaches 24 hours.

However, such a steady load on the station is never realized in actual practice because there are load curves with a variable characteristic. The consumers require their small or large powers in accordance with the demands of their activities. Thus, the load demand of one consumer at any time may be different from that of the other consumer although the single consumer have a varied non-repeatable loading. This means that the derived variation do not stand only for a consumer from the others but the load may be varied for the same consumer from time to another (season or even a day / evening) or a day to another (holiday or rest day to duty day for example) and so on. The result is that a load on the power station varies from time to another.

I- Requirements

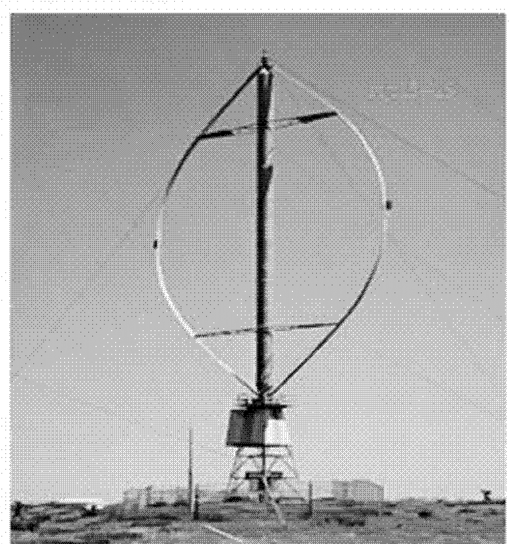
The variable load on a power station and consequentially on the generators inside it introduces many perplexities in its operation. This aim should be considered in the process of the design that must be reflected in either the single line diagram or the layout itself or in both. For more importance, some of the basic effects of variable load on a power stations can be tailored as follows.

a) Equipment

The variable load on a power station necessitates to install additional equipment in the designed system. For example in steam power stations, air, coal and water are the raw materials for this plant. In order to produce variable power, the supply of these materials will be required to be varied correspondingly.

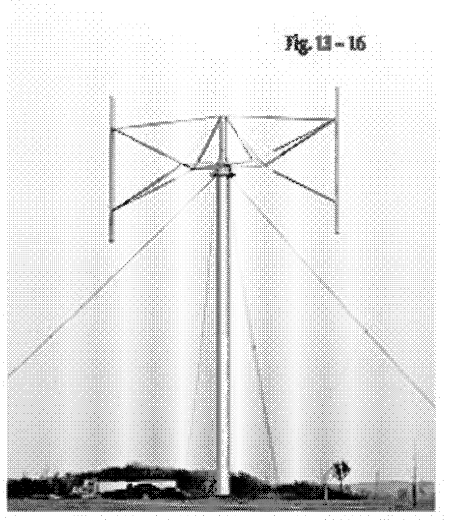
For instance, if the power demand on the plant increases, it must be followed at the same time by an increased flow of coal, air and water to the boiler in order to meet the increased demand magnitude.
Therefore, additional equipment has to be introduced in the design to accomplish this job. As a matter of fact, in modern power plants, there is much equipment devoted entirely to adjust the rates of supply of raw materials in accordance with the power demand made on the plant. This big requirements are appeared due to the technological revolution in engineering fields. It takes more efforts for the nuclear power stations where the attention is directed to a safety and security principle. Thus, the regulation of operations and restrictions in general would be accurately fulfilled while the labor must be well trained and they have a high level of experience.

b) Energy production cost



The variable load on the plant increases the cost of the production of electrical energy. An alternator operates, usually, at maximum efficiency near its rated capacity. If a single alternator is used, it will have poor efficiency during periods of light loads on the plant. Therefore in practice, a number of alternators with different capacities are installed so that most of the alternators can be operated at nearly full load capacity. However, the use of a number of generating units increases the initial

cost per kW of the plant capacity as well as floor area required. This leads to the increase in production cost of energy so that this subject may be reflected to the lay out design.
Obviously, a single generating unit (i.e. alternator) will not be an economical proposition to meet this varying load because a single unit will have a very poor efficiency during the periods of light loads on the power station.
The selection of the number and sizes of the units is decided according to the annual load curve of the station which is used to get the annual load duration curve. The number and size of the units are selected in such a way that they correctly fit the station load curve. Once this underlying principle is adhered to, it becomes possible to operate the generating units at or near the point of maximum efficiency. Usually, the optimal power flow software is used to get the best point of operation regularly.


Fig. 13 – 16

After that, the power stations can be classified as said before in this book but after adding these Renewal Stations. Then, power stations wickbe such as:

1- Hydro Power Station
2- Thermal Power Station
3- Nuclear Power Station
4- Diesel Power Station
5- Solar Sun Radiation Station
6- Wind Farm Station

Therefore, the choice of station suitable for the design must include too, these renewal energy stations. Thus, as a subject as a whole the general view for all types of stations may be indicated shortly.

II- The Selection of Units

The selection of number and sizes of the generating units depends on some points, which should be kept in view. They are:

1- The quantity and size of the units should be so selected that they approximately fit the annual duration load curve of the station.
2- The units should be preferably of different capacities to meet the load requirements. Although the use of identical units (i.e. having the same capacity) ensures saving in cost, they often do not meet the load requirement.
3- The capacity of a plant should be made ass a reserve percentage of about 15 to 20 % more than the maximum demand of the station in order to meet the. future load requirements.
4- A spare generating unit should be accounted in the design so that repairs and overhauling of the working units can be carried out.
5- The tendency to select a large number of units of smaller capacity, to fit the load curve very accurately, should be avoided, completely. This is considered because the investment cost per kW of the capacity increases as the size of the units decreases.
It would be mentioned that number and sizes of units can be selected for example that a power factor of the machines is assumed to be 0-8, while the output of the generating units available will be 8, 16, 20 and 24 MW. There are several possibilities for the selection. However, while selecting the size and the number of units, it has to be borne in mind, for the design base, some major factors to be considered:

(a) One set of highest capacity should be kept as a standby unit. A unit in the traditional power stations equals a group of generating units in the renewal energy stations.
(b) The units should meet the maximum demand on the station. Sometimes, this maximum demand power my be divided on two adjacent stations where both renewal energy and traditional stations

are considered together as an integral compound station.
(c) There should be overall economy although this principle may be taken out of consideration for the utilization of the renewal energy in the location.

The load duration curve should be considered in order to cover the performance of the load curve.

III - Load Meeting

The aim of the design of a station of a part of it is concluded in the covering for any variation of the loads according to the characteristic of the load curves. This design may be considered in the next part.

1- Individual Station Design

The total load on a power station consists of two parts *as a* **base load and a peak load. In order to achieve overall economy,** *the best method to meet load is to interconnect two different power stations. This may raise the reliability factor for the general operation for both together.* **The more efficient plant is generally, used to supply the base load and it is known as** *base load power station* **for the Load Meeting. The less efficient plant is always used to supply the peak load. There is no fast rule for the selection of base load and peak load stations as it would depend upon the particular situation. For example, both hydro-electric and steam power stations are quite efficient and any type of them can be used as a base load although a peak load station must meet a particular requirement.**

2- The design as a part of the network

Various problems (operation and maintenance) facing the power engineers are considerably reduced by interconnecting different power stations in parallel through connectors. Although interconnection of stations involves extra cost (considering the benefits derived from such an arrangement), it is gaining much favor nowadays.

3- Advantages

Some of the advantages of interconnected system (United Power System), in the subject of the station design, may be listed below.

(a) Peak loads

An important advantage of interconnected system is that the peak load of a power station can be exchanged between two or three stations. If the load curve of a power station shows a peak demand that is greater than the rated capacity of the plant, then the excess load can be shared by other stations interconnected with through the dispatching center.

(b) Older plants

An interconnected system facilitates the utilization of older and less efficient plants to carry peak loads. Although such plants may be inadequate during individual use, they have a sufficient capacity to carry short peaks of loads when interconnected with other modern plants. Therefore, interconnected system gives a direct key to the use of obsolete plants. Also, the renewal energy stations may be considered if they are connected to united network.

(c) Economic operation

It is known that an interconnected electric power system makes the operation of concerned power stations, under design, quite economical. This condition may be appeared because the sharing of load among stations is arranged in such a way that more efficient stations work continuously throughout the year. It may be applied at a high load factor while the less efficient plants must work for the durations of peak load hours only.

(d) Increased diversity factor

The load curves of different stations in an interconnected system are generally different so that the maximum demand on the system is much reduced as compared to the sum of individual maximum demands on different stations. This means that the diversity factor of a power system will be improved, thereby increasing the effective

capacity of the system.

(e) Plant reserve capacity

A power station must have a standby unit for emergencies in general as an individual station. However, when several power stations are connected in parallel, the reserve capacity of the electric system will be greatly reduced. This may increase the operation efficiency of the electric power system and its load factor.

(f) Reliability of supply

The interconnected system increases the reliability of supply. If a major breakdown occurs in a power station, continuity of supply can be maintained by other healthy stations or even one of them. Also, the optimal power flow in electric power networks may be better with the united power systems.

4- Disadvantages

It is important to define the difficulty of operation of a renewal energy station in a power system because it needs another station for each to be connected. This point may be disappeared if the generated power from the renewal energy station is less than the required local power. This may be explained through the drawing given in Fig. 13 - 17 where only a rectifier station will be required to supply the local load. Thus, we have three conditions as they may be tailored as:

a) The generated load and the local load are equal

The condition of operation when the generated load is equal exactly to the local consumed load is an ideal operation. This case can be expressed mathematically by the formula:

$$I_g = I_1 \qquad (13-6)$$

Then, no current transfer between the united network and the local renewal energy station and so I3 = 0. This is an ideal operation that can not be happened at all while the other two cases are the most practical.

b) The generated load is greater than the local load

This case means mathematically that:

$$I_g ? \ I_1 \qquad (13-7)$$

This condition may be expressed as a generation power can not find a load to supply leading to a danger case of operation or what is known technically as the instability.
It is the worst condition because the connection between the united network and the local DC station must be done through a converter station. This is an expensive part of the network as a whole where the excess of the generated power can be transferred to the united network.

c) The generated load is less than the local load

Here we have that:

$$I_g ? \ I_1 \qquad (13-8)$$

This means that the load in the location is greater than the generated power from the renewal energy station although it works at its maximum demand. This case is better than the above if the united network is connected to the location. Then, the power system may feed the load by the current difference between the generated DC power and the local load. It is a DC power so that only a rectifier station may be required. It is instead the converter as it is more simple and cheaper.
In general for exact connection a converter station must be a link between both a DC renewal energy station and the united AC electric system.

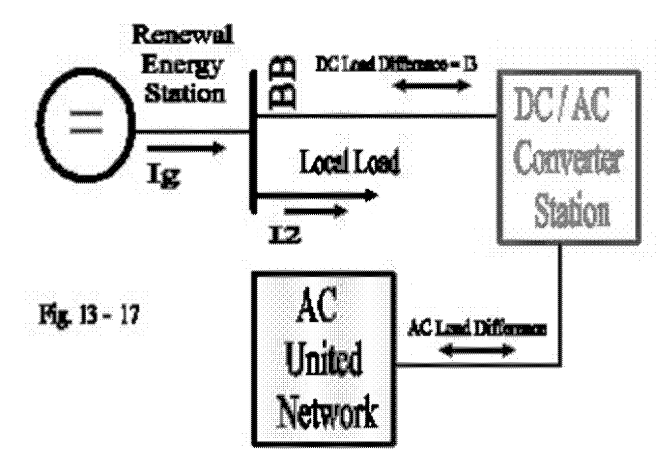


Fig. 13 - 17

Chapter IVX

COST EVALUATION

The problem of cost evaluation appears to be one of the basic factors involving the installation of electric stations as well as the lines between them. This aims to supply the consumers at the terminals of the power system with the required energy. Then, the subject of cost evaluation may be one of the vital items that should be analyzed scientifically.

14 – 1: COSTING METHODS

There are a lot of methods for the calculations of cost in all systems of investment but the primary methods for calculation of the equivalent uniform annual-cost (EUAC) of an asset may be needed to determine the station cost under design. The better way of alternatives according to the annual-cost comparison can be based and then selected. The alternative selected using (EUAC) must be the same as that chosen using present- worth or any other evaluation method; that is, all methods should result in identical decisions, just in a different manner. Then, fundamental items of EUAC can be tailored now.

1- One cycle calculation of each alternative is a base, when the alternatives have different lives.
2- Evaluating an asset having a salvage value, using the salvage sinking fund method, depends on the asset initial cost, salvage value, life, and interest rate
3- Exception of using the capital- recovery- plus –interest method.
4- Choice of the best alternative, given their initial costs, salvage values, lives, amount and time of the operating costs, and interest rate.
5- Evaluation of a perpetual investment, given the initial cost of the asset, amount and timing of disbursements, and rate.
These problems may be effective as more details would be presented in the next paragraphs.

I- Period with Different Lives

EUAC (equivalent uniform annual cost) is another method that is commonly used for comparing alternatives. As illustrated , the EUAC means that all disbursement (irregular and uniform) must be converted to an equivalent uniform annual cost, that is, a year-end amount which is the same each year. The major advantage of this method over the same number of years when the alternatives have different lives. When the EUAC method is used, the equivalent uniform annual cost of the alternative must be calculate for one life cycle only. Thus, as its name implies, the EUAC is an equivalent annual cost over the life of the project. If the project is continued for more than one cycle, the equivalent annual cost for the next cycle and all succeeding cycles would be exactly the same as for the first, assuming all cash flows were the same for each cycle. The EUAC for one cycle of an alternative therefore represents the equivalent uniform annual cost of that alternative forever.

II- Salvage Sinking (Fund Method)

When an asset of a given alternative has a terminal salvage value (SV), there are several ways by which the EUAC can be calculated. This section presents the salvage sinking fund method, probably the simplest of the three discussed in this chapter. This is the method that is used hereinafter. In the salvage sinking-fund method, the initial cost (p) is first converted to an equivalent uniform annual cost using the A/p (capital-recovery) factor. Also, the salvage value, after conversion to an equivalent uniform cost via first cost can be determined. The computations may be represented by a general equation:

$$EUAC = p(A/p, I\%, n) - sv\,(A/F, i\%, n) \quad (14\text{-}1)$$

Naturally, EUAC is nothing more than an A value, but it is referred to as EUAC.

Example (14 - 1):

Calculate the EUAC of a machine that has an initial cost of 8000 $

and a salvage value of 500 $ after 8 years. Annual operating costs (AOC) for the machine are estimated to be 900 $, and the interest rate of 6 % is applicable.

SOLUTION

The cash-flow digram (Fig. 14 - 1) requires the value of EUAC

EUAC = A1 + A2

Where A1 = annual cost of initial investment lees salvage value ,E q. (14 - 1)

A2 = annual maintenance cost = $ 1238

EUAC = 1238 + 900 = $ 2138

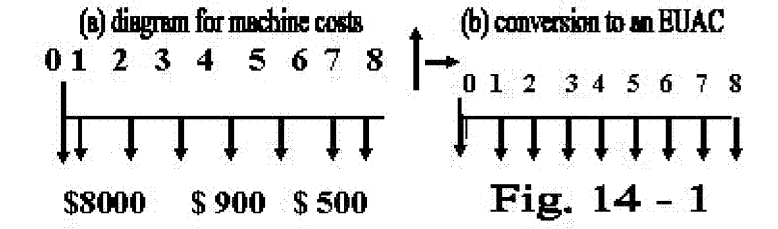


Fig. 14 - 1

Comment:

Since the maintenance cost was already expressed as annual cost over the life of the asset, no conversions were necessary. The simplicity of the salvage sinking-fund method should be obvious form the straightforward calculations shown in this example. The steps in this method are the following:

1-annualize the initial investment cost over the life of asset using the A/p factor.

2-Annualize the salvage value using the A/F factor.

3-Subtract the annualized salvage value form the annualized investment cost.

4-Add the uniform annual costs to the value from step 3.

III- Salvage Present *(Worth Method)*

The salvage present-worth method is the second method by which investment costs having salvage values can be converted into an EUAC. The present worth of the salvage value is subtracted from the initial investment cost, and the resulting difference is annualized for the life of the asset. The steps that must be followed in this method are the following:

$$EUAC= [p - sv\ (p/f,\ I\%,\ n)](A/p,\ I\%,\ n) \quad (14\text{-}2)$$

1- Calculate the present worth of the salvage value via the p/f factor.
2- Subtract the value obtained in step 1 from the initial cost p.
3- Annualize the resulting asset difference using the A/p factor.
4- Add the uniform annual costs to the result of step 3.

Example (14 - 2):

Compute the EUAC for the machine detailed in Example 14 -1 using the salvage present-worth method.

Solution

Using the steps outlined above and Eq .(14 - 2),
EUAC = [8000 -500(p/f, 6% , 8)] (A/p, 6% ,8) + 900 = $ 2138

IV- Capital-Recovery-Plus (Interest Method)

The final procedure that will be here for calculating the EUAC of an asset having a salvage value is the capital-recovery-plus-interest method. The general equation for this method is

$$EUAC=(p - s\ v)(A/p,\ i\%,\ n)+s\ v(i) \quad (14\text{-}3)$$

In subtracting the salvage value from the investment cost before multiplying by the A/p factor, it is recognized that the salvage value will be recovered. However, the fact that the salvage value will not be recovered for n years must be taken into account by adding the interest (SVi) lost during the asset' s life. Failure to include this term would assume that the salvage value was obtained in year 0 instead of year n. Only 5 steps should be followed for this method as follows:

1- Subtract the salvage value from the initial cost.
2- Annualize the resulting difference with the A/P factor.
3- Multiply the salvage value by the interest rate.
4- Add the values obtained in steps 2 and 3.
5- Add the uniform annual costs to the result of step 4.

Example 14 - 3:

Use the value of Example 14 . 1 to compute the EUAC using the capital-recovery-plus-interest method

Solution

From E q. (14 . 3) and the steps above,

EUAC = (800 - 500)(A/p, 6%, 8) + 500(.06) + 900 = 2138 $

Since results do not depend on the used method, it would be good procedure hereafter to apply only the simplest one in order to avoid unnecessary errors caused by mixing the methods. Then, the salvage sinking fund method would be implemented.

V- Comparing Alternatives by EUAC

The equivalent-uniform-annual-cost method of comparing alternatives is probably the simplest of alternative evaluation techniques. Selection is made on the basis of EUAC with the alternative having the lowest cost being the most favorable. Obviously no quantifiable data must also be considered in arriving at the final decision, and generally, the alternative having the lowest EUAC should be selected.

Perhaps the most important rule to remember when making EUAC comparisons is that *only one cycle* of the alternative must be considered. This assumes, of course that the costs in all succeeding periods will be the same. While it is true that the cost of an asset today will portly be much lower than the cost of the same asset 10 years from today because of inflation. It must be remembered that, usually, the costs of the other alternatives would increase as well. The analytical methods presented here are mainly for the purpose of making comparisons not for determining actual costs while the same evaluation would be reached. This would be at any future date as long as all costs increased proportionality.

Obviously, when information is available as the costs of certain assets will increase or increase considerably. Because of technical improvements or increased competition, these factors must be taken into consideration in the final decision.

Example 14 - 4:

The following costs are proposed for two equal-service tomato peeling machines in a food canning plant:

Table 14 - 1: The deduced values

Item	Machine A	Machine B
First cost ($)	26000	36000
Annual maintenance cost ($)	800	300
Annual labor cost ($)	11000	7000
Extra income taxes ($)	……	2600
Salvage value ($)	2000	3000
Live years	6	10

If the minimum required rate of return is 15 % which machine should be selected?

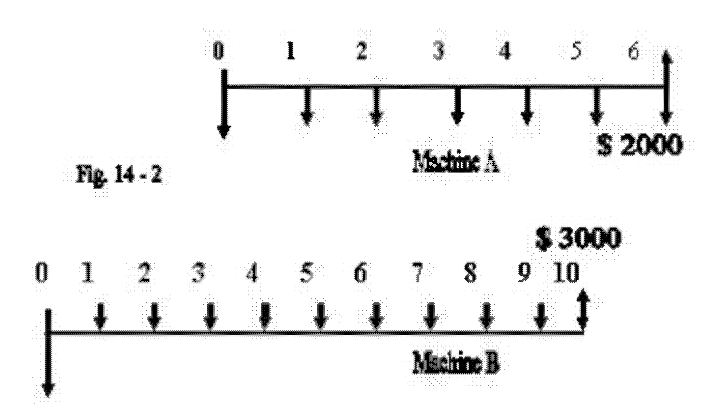


Fig. 14 - 2

Solution:

The cash-flow diagram for each alternative is shown in Fig. 14 - 2 where the EUAC of each machine using the salvage sinking-fund method can be derived with the help of Eq. (14 - 1) in the form:

$$0 = -P + \sum_{t=1}^{n} CFt\,(P/F,\ I\ \%,\ t) \qquad (14-4)$$

Select machine b, since EUAC (B) < EUAC (A).

Years n before the first cost and stated return is realized, that is, for each alternative determine the n value such that The alternative with the smaller n value is selected. If I = 0 % , the no return payback period is computed. Comparison using payback-period analysis may give a different result than doe's present-worth or EUAC analysis because it neglects all each flows after the time n and it also overlooks the time value of money if I = 0 %.

VI - EUAC of a Perpetual Investment

Sometimes it is necessary to compare alternative that can be expected to have a perpetual life, such as flood-control dams or irrigate projects. In the presented analysis, it is important to recognize that annual cost of perpetual initial investment is simply the annual cost interest on the initial lump sum. That is, if the government invests \$ 10000 in a certain public work project, the EUAC of the investment would be \$ 10000 (0.04) = \$ 400 for interest rates of 4 %. This computation is easy to understand when it is realized that the government could let an investor pay the \$ 10,000 for the public works project. Then, it pays the investor the \$ 400 per year for ever. If the interest rate is 4 % since both persons would receive only \$ 400 per year perpetually costs recurring at regular or irregular intervals. This will be handled exactly as conventional EUAC problems as all other costs must be converted into equivalent uniform annual costs for one cycle. They are thus automatically annual costs for ever as discussed above.

14 – 2: GRAMMARLESS LOSSES

Nowadays, the fuel consumption is floating on the surface of the most important problems in the world so that all efforts were directed towards the saving of the traditional energy sources which appear to be the simple used one. On the other hand, the renewable energy is strongly introduced into the field of energy sources to be utilized either beside or instead of traditional types. Both time and effort of Scientists on Globe are concentrated for this purpose to minimize the energy loss.

The traditional energy produce a lot of pollution materials and substances that pollute the environments surrounding our life. Although the spread utilization of such item , the need for a new type of energy generation would be introduced to replace the polluted area by another clean. However, the utilization of energy sources must be an economic problem to decide its use where the traditional fuel is still the most economic one.

The required concept to cover the suggested problem can be appeared in the coding process utilized the consumed energy. Otherwise, it is needed to managing the problem of utilization of energy. This means that we must control the energy consumption in the network either though the generation or in the transmission or even in the distribution systems of the network.

I - LOSS ANALYSIS

It is known that there is a minimum value for energy loss in networks where the parameters of the circuit consume it. So, it is defined as the technical loss. It takes different shapes in the various stages of a network such as generation, transmission, distribution and the utilization principle.

Alternatively, the generated loss may depend mainly on the type and used fuel but this differs for the transmission section where the great effect included in the reactive power generated in the network and consequently active and reactive power losses may be formulated mathematically. It is known for the active power loss although the reactive power loss can play a great role. The equivalent circuit Π for transmission lines presents that the loss will be a

function of the circuit parameters as inductive reactance (X_L), capacitive reactance (X_c) and the resistance R.
The loss must appear as reflected by the power factor triangle as both active and reactive loss can be included together when the reactive power loss depends on the harmonic presence as well as the inductive and capacitive parts of the given circuit.
The transmission system is the most economic part of a network due to the high level of transmitted voltage level in order to decrease the loss. Although the transmission loss is minimized in this part of the network, the loss in the reactive power appears to be the main goal. This leads to the important of improvement of power factor in transmission systems of a network. Therefore, the loss in transmission and distribution parts can be tailored into two fundamental items as active and passive where the active power loss (PL) means the actual consumption and it is expressed through:

$$PL = I^2 . R \quad (14-5)$$

Also, the reactive loss (QL) according to the equivalent circuit may be deduced in the form:

$$QL = (Iz)^2.X_L + ((I_{c1})^2 + (I_{c2})^2).X_c/2 \quad (14-6)$$

Whatever, the control angle plays a great role in this concern as assuming that both terminal voltages (V_1) and (V_2) are equal. This means that also both values of (I_c) are equal, and leading to a simple formula for the passive loss as a ratio to the sending end power (S) as

$$\frac{QL}{S} = \frac{Ic^2 . X_c + Iz^2 . X_L}{V . I} \quad (14-7)$$

This loss ratio (LR) can be simplified to

$$LR = (V/I)\left[\frac{4}{X_c} + \frac{\sin(a)}{2} . X_L\right] \quad (14-8)$$

Thus, the loss ratio may be clarified as a list of ratios to give the performance of this loss in any network and so, the ratios are listed in Table 14 - 2 with their maximum ranges which would be investigated now.

The final expression, under the consideration of constant ratio between voltage and current at the sending end (input impedance), for the loss ratio will be:

$$LR = \frac{Z_{in}}{X_L}\left[\frac{4}{M} + \frac{\sin(a)}{2}\right], \{2, (1 + N)\} \quad (14\text{-}9)$$

The required term in this equation will be specified as the loss term (K) in the range 2 – (N+1) as:

$$K = \frac{4}{M} + \frac{\sin(a)}{2} \quad (14\text{-}10)$$

This loss term is tested for the regions with respect to the first coefficient N.

The passive loss in a system depends on the assumed parameters where its values are highly decreased with the increase of parameter (N). This means that the presence of high ratio of inductance to the resistance of a line will decrease the loss but this result induced to open the effect of the M factor where the results were illustrating no effect practically on the loss term. Consequently, the last factor of the control angle should be tested to prove the real role of the control angle.

Table 14 - 2 : The ranges of maximum ratios

Ratio	Equivalent Expression	Range of Variation
Z_{in}	V / I	Constant
M	X_c / X_L	0.6 - 2.0
N	X_L / R	10 - 16
a	control angle	1 - 8

normal or overloaded. The overloaded connections lead to an overheating effect at the spot reaching the melting of the metal connectors and consequently the damage of the insulation holding this connection besides the external pollution.
The temporary connections (bad) are tailored into 4 different types such as loose, vibrated, overloaded and sparking connections where the last generates both overheat and ionization, leading to static charges with their negative hurting effect. The insulation can be damaged quickly since its life period will be reduced due to bad operations. This indicates that a fundamental training program must be considered as one of the vital subjects in the modern operation of united networks. Maintenance programs will be helpful with a good training. So, a routine maintenance of GL is important to save energy on our earth.
This means that a good management for energy loss alone specially that called GL will be very necessary. This proves a need for the creation of a special management department which may be divided into three major sectors for the conservation of energy as well as to prevent the loss in energy due to GL where each sector is directed towards a step of operation. Also, it may be mentioned that only transistor devices as TV, radio, etc. should be used while all lamp devices must be switched off to be out of operation.
These four sectors are defined as installation, operation, check quality and finally maintenance sectors to minimize GL. The quality control in industry either for electrical connections or for the used device and machines as utilities at the user ends is a sector. It may review the operation of such an equipment with different actual applications to check the performance and the suitability for use. This can be controlled through 3 sections as testing certificates before use and guarantee cards as well as the final step of operation test as a minimum level for the instruction of use including the catalogues. The operation sector is directly related to installation before operation check and the maintenance after operation. The maintenance may be a routine one while a capital maintenance means the replacement of damaged parts.
Finally, from these items it can be concluded, for the design consideration, that:

1 - The grammarless loss must be eliminated from power networks.
2 - The proposed active management for GL should be implemented an all networks through training and routine maintenance.
3 - TV programs for learning, explaining and training of GL will help
well in energy conservation.
4 - Devices must be checked by a special sector before use.
5- The control angle between bus voltages can reduce the loss.

14 - 3: ENERGY PRICEING

Nowadays, the fuel consumption is floating on the surface of the most important problems in the world so that all efforts may be directed towards the saving of the traditional energy sources, which appear to be the simple used fuel. The renewable energy is hardly introduced to the field of energy source to be utilized, either besides or instead of the traditional types of fuel.
The traditional energy produces a lot of substances that pollute the environments surrounding our life. Although the spread utilization of such item, a new type of energy generation would be needed to replace the polluted area by another clean one. However, the utilization of energy sources must be an economic problem to decide its use where the traditional fuel is still the most economic one. In spite of this condition the solar energy may be useful in far places and in shiny zones and where the required loads are small and far from the country network. This is a plus advantage for the use of solar energy.

I - ECONOMIC TARIFF

Today, some of the big national projects has been borne tending to help the industry and commercial situation in developing countries as in the advanced big countries. For example in Egypt there many projects such as TOSHKI in the south in order to higher the possibility of mutual connection with others in the field of exporting including the special private sector besides the governmental one. It should be noted that the change from the old unique directed

economy to another opened (depending on both individual private and investment sectors - either the local or the foreign capital for reforming the overall economy) to form a good and strong base is required.
In this concern, the consumption energy is a vital subject for reforming policy especially the routine energy either the consumed or the lost through the concept of management or pricing or even in the cost of the instruments and devices. This normally, takes more value with the electricity sector. This presents that the installed power can't be used totally over all the time where the economic tariff as the price of energy unit for a given country may be defined generally as:

$$\text{Tariff} = \frac{\textbf{total cost}}{\textit{total actual consumption}} \qquad (14 - 11)$$

II - TOTAL COST

The total cost means the total spent money for the given consumption at the end of consumers. This illustrated in a simple form where a complete covering for the items of a network up to the service of popular as spread on the Earth. Now, the value of electric consumption has been continuously increased on either the individual or the national levels so that the way to share in the capital assets may be the suitable. This leads the capital stock to higher step of economy instead the lazy position of the available capital of individuals though companies or banks. The social behavior should be varied with the appeared new shape of economy taking the consuming activities to be replaced by the production type and its relatives through the marketing and auxiliaries. This strategy will help in raising the investment consumption level through the reforming of used energy in different ways of electricity, water, sewage, cleaning communications and transportation. In this concern the actual consumption of the above equation is known as:

Consumption = Total installed energy - Unused energy - Dead energy (14 - 12)

If we return to Equation 14 - 11, the term of dead energy appeared in Equation 14 - 12 will be a vital amount specially with large values of spare power. However, the dead energy depends on the planning procedure that may fail sometimes according to the sudden variations in the social or political of a country so that this will be suitable if its value is minimized as possible as it can.

Recently the actual saving in this item can be realized as the Arab Countries go (for example) to the policy of mutual connection between the own national networks and consequently the spare energy for each one can be really disappeared due to the overall spare in general network. This will decrease the total cost in equation 14 - 11 and should reduce the tariff of the energy.

III - LOSS COST

The required concept to cover the suggested problem can be appeared in the coding process utilized for the implementation of the consumed energy. In other words, it is needed to managing the problem of utilization of energy. This means that we must control the energy consumption in the network either though generation or transmission or even distribution systems. Otherwise, minimizing the fuel loss is still the main aim for the generation process as a whole while the electric loss in the generation step appears to be within the acceptable region.

Each sector has its own character from the point of view of energy loss. The first part losses its energy in both the normal technical electrical loss besides energy loss which is clear in the heat loss. Otherwise the heat loss is the most important factor in the problem of conservation of the energy. It may be expressed in terms of the fuel that used in the burning process. So, it is dependent on the fuel characteristic as well as the fuel burning efficiency where the new tendency goes to implementing co-generation or combined cycles systems.

The second stage in a network is the transmission where a new factor

would be appeared to decrease the utilization of input energy. This new factor will be the induced reactive power in the transmission system due to the self parameters of the system. In this sector the reactors must be installed at the terminals of long EHV and UHV lines to develop their performance. Also, a synchronous condenser would be required to compensate reactive power in order to decrease the raising of voltage. These condensers may improve the power factor in the transmission system leading to minimizing the power active loss in the sector. Actually such concepts are used in the 500 kV system of Egypt.

The third section is the distribution system where the problems of both transmission and the fourth section (utilization) will be reflected on its performance so that the reactive power troubles may be one of the important parameters of loss. Otherwise the electrical active loss can be the nominal one that can't be modified. The other part of loss is the social loss which includes the different types of consumers. Some of them may try to take energy or some without counting. Others have damaged electric counters while a little of them can't pay for energy for commercial reasons. All these problems can be solved by good maintenance and management. It is known that the item of loss is one of the 5 branches of cost. The cost of unused energy must be treated through the planning but the cost of network loss can be tailored different types of loss in the network. Although the transmission loss is minimized in this part of the network, the loss in the reactive power appears to be the main goal. This is leading to the importance of the improvement of power factor in transmission systems. However, the distribution network takes a small importance in this field and consequently the concentration for the details of some items in the distribution system may be required to be analyzed. The energy management is one of the vital problems that may cover its use.

Energy loss in the distribution systems can be classified into three groups such as social, technical and grammar use losses. The companies of electric distribution cover technical loss while they may not treat completely the problem of social losses in spite of its importance from the economic point of view.

The terms of this final Equations may be explained in a general form

where the nominal loss is equivalent to the technical loss that must be presented in a circuit as active loss which cannot be avoided at all. On the other hand, the second term expresses that loss due to the uncontrolled behaviors of some persons such as the different occasions of society either individual or grouping type or even the national one.

IV - POWER FACTOR IMPROVEMENT

However, the most important factor for the operation of a network is concentrated in the power factor because it is a money. This means that a good power factor leads to increase the active power (or reduction of reactive power loss) so that a corresponding money will be saved. The last term of Equation above (14 - 12) means the loss due to the utilization process and it is related to the presentation of reactive power in the network leading to the technical loss. Whatever, this loss of that type can be controlled generally, on the basis of technical treatment for the electrical circuit. This reactive power may be appeared with the use of some gas lighting lamps of the low p. f. character which reaches 0.4 in most cases of applications specially with a large number of small spread amounts as well as the utilization of motors in many steps of home or workshop needs.

For such problems the power factor modifiers must be implemented as condenser and synchronous machines and so the reactive power can be reduced increasing the excess of actual active power for the same value of generated power. This is a very important view where this will help directly in the given above dead energy. It increases the spare power for the same generation and finally leads to a decrease in the total cost of Equation 14 - 12 can be defined by n % of the initial value of cost. The increase of the utilized energy due to the power factor improvement would be m % of the initial consumption, and therefore, the save in the tariff can be expressed mathematically. From this given above analysis, it is concluded that:

1 - Tariff reduction can be easily reached through reforming of energy consumption and power factor modification.

2 - The connection between all national networks of the Arab Nations

as well as the present Europe network will help in decreasing the tariff.

3 - The dead energy must be minimized as possible to reduce the tariff of energy as a whole.

14 - 4: CORRELATION OF ENERGY COST

The energy costing is a known type of Engineering problems in all countries due to the modification every day in the style of equipment for control or even in protection schemes. Thus, it has been studied in details while the characteristics of tariff are defined well in various ways. This tariff may differ from a country to another as well as it may differ in the inside places in the single country. On the other hand, the new types of stations and the performance of optimal power flow in electric networks may direct the problem of costing for the consumed energy to include the varied shape of load curves. This transforms the work into a created zone for applications.

Table 14 - 3: The basic tariff for the domestic sector in Egypt

Energy, kWh	100	200	300	400	500	1000	2000	3000	4000
Tariff base	180	480	860	1280	1740	5290	15290	27290	39290
P_{av} (/ kWh)	1.8	2.4	2.86	3.2	3.48	5.29	7.645	9.096	9.82
RRP (base)	1	1.33	1.58	1.77	1.93	2.93	4.24	5.05	5.69
RRP (stripe)	1	1.33	1.19	1.11	1.08	1.52	1.44	1.18	1.07

However, the price of energy must be updated according to the modification in the system. The tariff of electric energy in Egypt (as an example) is considered for the technology of evaluation. The principle of tariff for energy consumption has been widely investigated for a long time, consequently, this tariff in Egypt is currently based on the striped style as listed in Tables 14 - 3 & 14 - 4.

Table 14 - 3 related to the domestic loads while Table 14 - 4 gives the tariff for the commercial sector including the industrial loads. The rate of rise of price (RRP) for each stripe is accounted for two conditions (relative to the base strip and with respect to the stripe itself). Its value is growing with the consumed energy in the case of base evaluation in the two sectors.

Table 14 - 4 : Basic tariff for the commercial sector in Egypt

Energy, kWh	100	200	300	400	500	1000	2000	3000	4000
Tariff base	210	570	1210	1970	2850	7850	19850	33850	46850
P_{av} (/kWh)	2.1	2.85	4.03	4.925	5.7	7.85	9.925	11.28	1.96
RRP (base)	1	1.35	1.91	2.34	2.71	3.73	4.72	5.37	5.69
RRP (stripe)	1	1.35	1.41	1.22	1.15	1.37	1.26	1.13	1.06

Since the present section related to a high mathematics, the used signs and symbols must be defined. In this moment the main energy pricing n*omenclature* may be listed in Table 14 – 5 while main statistical parameters are given in Table 14 - 6. Finally, Table 14 - 7 presents standard statistical factors and time correlation parameters.

I- Energy Price

The pricing of energy can be formulated by two sections of cost as given by:

$$\textbf{Total Cost} = \textbf{Fixed Cost} + \textbf{Running Cost} \qquad (14 - 13)$$

This equation means that the costing of energy must depend on, firstly, the capital cost of stations (Power Stations, Substations) and the connection between them (Connectors) with the ends of utilization (Loads). Secondly, the cost depends also on the running cost, which means the consumed power, where the presented work is

concentrated to solve the problem of evaluation for both sides (*customers and Electricity Company*). This has more importance in some countries as it will be concluded later. Then, a modification for the process of costing may be needed and therefore, the problem could be correlated.

Table 14 - 5 : Main Energy Pricing *Nomenclature*

symbol	title
L. E.	*Egyptian pound*
P. T.	*Egyptian coin (100 P. T. = L. E.)*
E_t	*total energy consumed*
P_m	*price of average in the strip m* th
KWh_i	*energy reading for the i* th *month*
P_i	*price of energy for the i* th *month*
P_{av}	*monthly average price*
P_i	*instant recorded reading for the i* th *month*
P_{i1}	*recorded reading for the i* th *month*
n_c	*number of customers in the distribution network*
E_1 , E_2 & E_3	*overall value of energy in the* 1^{st}, 2^{nd} & 3^{rd} *stripe, respectively*
e_2	*value of energy inside the* 2^{nd} *stripe and less than* E_2
e_3	*value of energy inside the* 3^{rd} *stripe and less than* E_3
T	*month time (period)*
T_i	*The period of i* th *month*

The fixed cost will be omitted out of this study in order to concentrate the analysis on the energy only. The process of determination of the tariff contains the average price of the energy, which can be specified to each sector to cover all possible variations in the loads of customers in the deduced shape of the stripes in KWH. The average monthly price P_{av} in the units of L. E. for the total energy (E_t) may be formulated as a function of the total energy used in the units (KWh):

Table 14 - 6 : Main Statistical Parameters

symbol	title
R_i	*energy reading for i th month*
X	*mean value of the population measurements*
X_i	*reading at the i th month or day or hour*
X_w	*weight load mean*
F	*cumulative frequency for the class before the middle class*
L_{md}	*lower boundary of the middle class*
C	*class interval of median class*
D_b	*difference between frequency of middle class and the next*
μ	*mean value of the samples*
f	*frequency of readings*
X_g	*grouped mean*
M	*midpoint point of each class (group)*
f_{md}	*frequency of the middle class*
D_a	*difference between frequency modal and before one*
P	*Pearson Ian coefficient of skew ness*

$$P_{av} = (1/(E_t)) \times \sum_{i=1}^{n_c} (P_i \times KWh_i) \qquad (14 - 14)$$

This average price should be equivalent to that deduced according to the stripes of the customers where they have m classes for each sector and the price in each can be remarked as P_m for the m^{th} stripe (It varies between 1 and 9 as indicated in Tables 14 - 3 and 14 - 4). Then, the average price will obey the same given expression in eq. (14 - 14). The developed static and dynamic values for the tariff of both mentioned sectors above are calculated and listed in Tables 14 - 8 and 14 - 9. All values are based on the P. T. units.

Table 14 - 7 : Standard Statistical Factors and time Correlation Parameters

symbol	title
RRP	*rate of rise of price*
N	*number of population*
S	*standard deviation for the population*
W_i	*weight of reading of the i th month or day or hour*
t_i	*time increase in i th month*
n	*number of samples* ($n < N$).
σ	*standard deviation for the samples*
α	*Correlation factor for energy consumption*
β	*Correlation factor for load curve (unused energy)*

Table 14 - 8: Energy price (in P. T.) for the domestic sector in Egypt

Energy from to (kWh)	0-100	100-200	200-300	300-400	400-500	500-1000	1000-2000	2000-3000	3000-4000
Energy cost	180	300	380	420	460	3550	10000	12000	12000
Energy price	1.8	3	3.8	4.2	4.6	35.5	100	120	120
RRP (base)	1	1.66	2.11	233	2.55	19.72	5555	66.66	66.66
RRP (dynamic)	1	1.66	1.26	111	1.09	7.71	2.81	1.2	1

It is remarked that RRP for the base conditions is highly increased with respect to the initial cases of Tables 14 - 3 & 14 - 4. However, the dynamic values were vibrated between 1 to 5.68 (instead of 1 to 1.37) for industrial loads and 1 to 2.81 (instead of 1 to 1.52) for the domestic. This means that the system of accounting is directed to protect the small customers. Hence, the computed cost difference between the dynamic and static tariff for the domestic and industrial loads is given in Table 14 - 10. The appeared rate of increase in the

cost is usually changed not only between stripes but also inside each stripe itself.

Table 14 - 9: Energy price (in P. T.) for the commercial sector in Egypt

Energy from: To (kWh)	0 - 100	100 200	200 300	300 - 400	400 500	500 - 1000	1000 - 2000	2000- 3000	3000 - 4000
Energy cost	210	360	640	760	880	5000	12000	14000	14000
Energy price	2.1	3.6	6.4	7.6	8.8	50	120	140	140
RRP (base)	1	1.71	3.04	3.61	4.19	23.81	57.14	66.66	66.66
RRP (*dynamic*)	1	1.71	1.77	1.18	1.15	5.68	2.4	1.66	1

II - Energy Consumption

Since the stripe price inside the total consumption depends on the actual period for the measurement, the applied date for the recording the consumed energy must be the same each month, i. e. a constant cycle of time (T). This process is very difficult due to the manual system for recording so that a deflection may be occurred in the determined consumed energy. The recorded reading P_i in a month x as due to the difference between instant reading R_i and last before R_{i-1} will be expressed mathematically by:

$$P_i = R_i - R_i - 1 \qquad (14\text{-}15)$$

This may be tailored for the first month as:

$$P_1 = E_1 + E_2 + e_3 \qquad (14\text{-}16)$$

The incorrect reading will be deduced if the next month (second) reading takes the form:

$$P_2 = E_1 + e_2 \quad (14\text{-}17)$$

Table 14 -10: The calculated cost difference between dynamic / static tariff

Energy	For domestic loads				For commercial loads			
kWh	Pitch P. T.	Energy cost / *average*	*Cost / strip*	*Rate of increase*	Pitch P. T.	Energy cost / average	Cost / strip	Rate of increase
100		180	180	0		210	210	0
125		300	255	45		356.25	300	56.2
150	75	360	330	30	90	427.5	390	37.5
175		420	405	15		498.75	480	18.7
200		480	480	0		570	570	0
225		643.5	575	68.5		906.75	730	176.7
250	95	715	670	45	160	1007.5	890	117.5
275		786.5	765	21.5		1108.25	1050	58.2
300		860	860	0		1210	1210	0
325		1040	965	75		1600.62	1400	200.6
350	105	1120	1070	50	190	1723.75	1590	133.7
375		1200	1175	25		1846.87	1780	66.8
400		1280	1280	0		1970	1970	0
425		1479	1395	84		2422.5	2190	232.5
450	115	1566	1510	56	220	2565	2410	155
475		1653	1625	28		2707.5	2630	77.5
500		1740	1740	0		2850	2850	0
600		3174	2095	1079		4710	3350	1360
700		3703	2450	1253		5495	3850	1645
800	355	4232	2805	1427	500	6280	4350	1930
900		4761	3160	1601		7065	4850	2215
1000		5290	5290	0		7850	7850	0

Where e_2 is the value of energy in inside the level of this stripe where its value is less than E_2.
If $e_2 + e_3 < E_2$, a vital mistake will be illuminated on the surface in the

estimated total cost of the consumed energy. Whatever, this cost does not touch the principle of tariff at all, and so, a correlation factor may be needed.

III - CORRELATION FACTOR

It is well known that the load curve for a specified place cannot be the same every day due to the performance of its variation, and so, the speech about all populations of loads may be impracticable. Hence the concept of simulation (sampling) may be the way to investigate the overall characteristics of a load.

However, it will be a step in the way to cost the energy consumption in the network. The sample must reflect the over all view of consumers in the studied field since it may be for only one sector of customers.

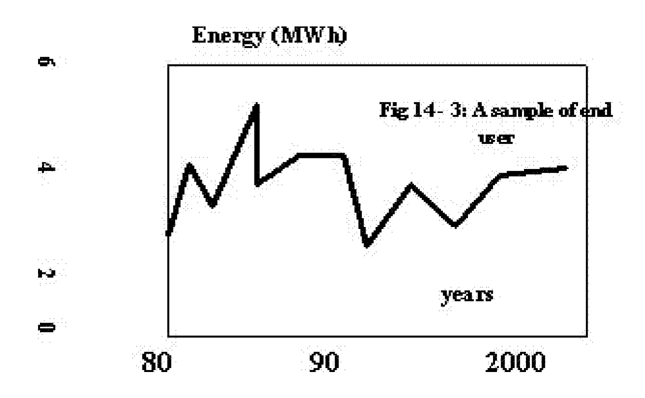


Fig 14- 3: A sample of end user

Two directions for the variation in a random way are needed. The first is the change in the number of customers connected at the ends of the distribution network while the second will be the continuous addition for due to consumers or all together.

There are two axes for the possible mistake in the process of accounting to find the total cost for the consumed energy in a certain reading or the sequence of measurements. The treated, here, such

mistake may be appeared in either the time period or the stripe zone. This can be illustrated in the following paragraph.

A sample of readings is registered for a time range of 20 years as given in Fig. 14 - 3 for the yearly energy consumption with an oscillated character.

The given values (Table 14 - 11) are true without any deviation on the bases of the presented tariff of energy in Egypt. The RRP for the energy consumption is presented also in Fig. 14 - 4 in (P. T. / KWh) where it is seen in raising shape as in Fig . 14 - 5. The deduced items affecting the studied correlation for energy cost will be listed in the Table 14 - 10 according to the tariff base of Tables 14 - 3 and 14 - 4.

Table 14 - 11: The Results of the studied sample

Till	Consumption (kWh)	Total cost (L. E.)	Average price (L. E./kWh)	Price grow ratio	Price to last year ratio
1981	2111	34.125	1.6165	1	1
1982	5665	99.552	1.7573	1.0845	1.0845
1983	7963	144.382	1.8131	1.1216	1.0342
1984	11948	230.932	1.9328	1.1956	1.0659
1985	16467	359.217	2.1814	1.3494	1.1286
1986	19316	436.592	2.2602	1.3982	1.0361
1987	22644	530.462	2.3426	1.4491	1.0364
1988	26029	626.692	2.4076	1.4894	1.0278
1989	29542	745.597	2.5238	1.5612	1.0482
1990	31376	793.012	2.5274	1.5635	1.0014
1991	33653	872.292	2.592	1.6034	1.0255
992	36862	1049.382	2.8467	1.761	1.0983
1993	39634	1242.707	3.1354	1.9396	1.1014
1994	41597	1444.302	3.4721	2.1479	1.1073
1995	44696	1715.172	3.8374	2.3738	1.1052
1996	48023	1999.782	4.1642	2.576	1.1085
1999	56200	337102.88	5.998	3.7104	

The axes of deflection will be induced as in the period T_i for a sequence of readings (R_i) with their energy (P_i) as a function of the exact month time T (usually T= 30 days). An excess time t_i may control the required aim where the index i means the 12 months (i = 1, 2,…,., …, 12). Then, the reading of energy for the month could be expressed as:



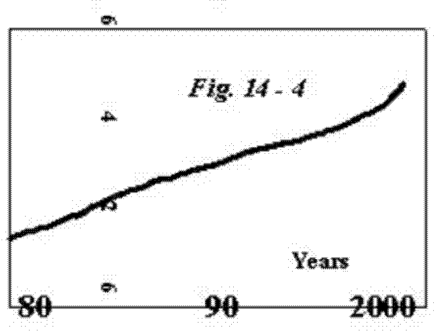
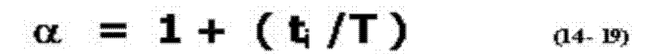


Fig. 14 - 4

$$R_i = T + t_i \tag{14 - 18}$$

The annual average energy can be expressed as the sum of monthly readings within the year divided by the number of months in spite of the number of readings may be different. This case represents the first axis of mistake that needs a correlation as proved by the extracted points of mistake (See Table 14 - 11). Thus, the second axis will be as given by equations 14 - 17 related to the time of the consumed energy in different periods leading to a mistake in the suitable stripe of the tariff. The selected readings in the studied example are presented in the Table 14 - 12 in order to illustrate the objective of the work. Whatever, the places of such mistake in the accounting process are shown in the raw numbers 1, 2, 3, 13, 14, and 16. These readings lead to an apparent cost which will be correlated. The correlation factor for the first item may be the division to get the average monthly reading and then another one to correlate the period, but only one factor (α) can proposed to cover both mistakes in the form:



$$\alpha = 1 + (t_i / T) \qquad (14\text{-}19)$$

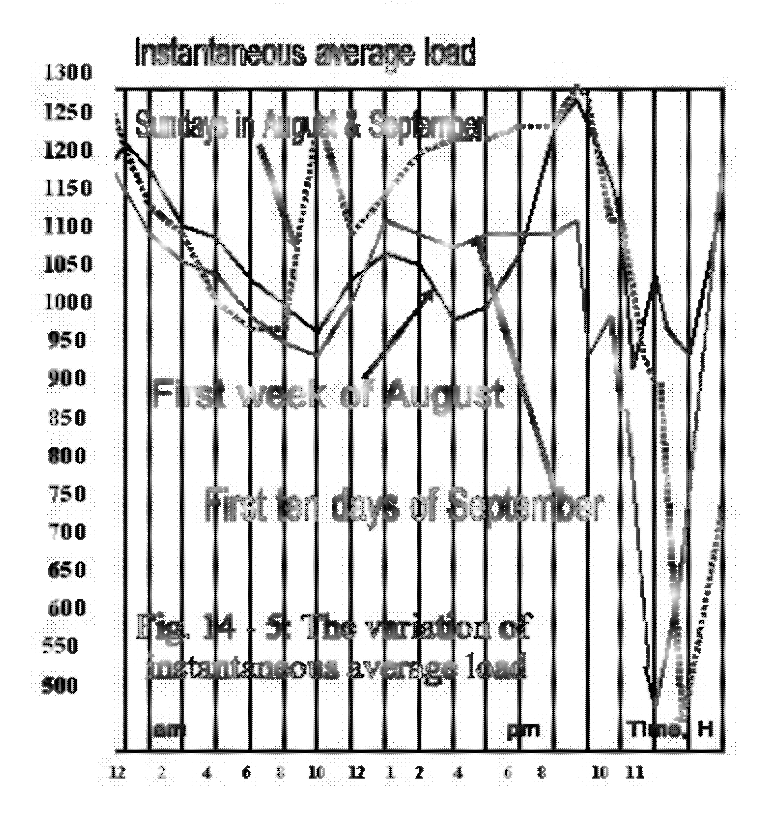


Fig. 14 - 5: The variation of instantaneous average load

IV - Statistical Measurements

Since the load is continuously varied, the consumed energy will not be a constant at all times. So, a new correlation factor may be required to adjust the performance of tariff as well as to bring the economic pricing in the right margin.

Also, this process appears to be a direct reflection for the statistical type of variation, and consequently, it may be taken according to the load curves of the network either in the end locations or in the city as a whole. The case of end users is analyzed above while the next part of work considered the load curves in Port Said City as an example for the idea of correlation. This leads to the importance of statistical parameters to cover the probable values during the period of study. The fundamental factors may be essential to represent all readings as they are tailored into the following items.

Table 14 - 12: The selected readings for comparison

Date *month* / year	KWh / *month reading*	*Energy* cost	Energy (KWh) /month	Cost/ month	*Equivalent* value (Average/ dynamic)	*Average* ratio	*dynamic* ratio
10/80	127/2	2.163	63.5	1.08	1.14	0.948	0.948
4/81	349/3	5.83	116.3	1.16	2.79 - 2.19	0.415	0.529
7/82	1497/5	27.42	300	5.48	8.6	0.637	0.637
2/83	300/1	5.55	160	5.55	8.6	0.645	0.645
10/84	160/1	3.065	301	3.06	3.84 - 3.66	0.798	0.837
9/85	301/1	8.385	151	8.38	8.6	0.975	0.975
9/86	151/1	3.325	300	3.32	3.6 - 3.32	0.923	1
7/87	300/1	8.6	300	8.6	8.6	1	1
5/88	300/1	8.6	250	8.6	8.6	1	1
12/89	250/1	5.4	124	5.4	7.15 - 6.7	0.755	0.805
7/90	124/1	3.04	102	3.04	2.97 - 2.5	1.02	1.216
8/91	102/1	3.09	524.5	3.0	2.44 – 2	1.266	1.658
5/92	1049/2	61.9	318.5	30.95	27.74- 18.66	1.115	1.54
3/93	637/2	42.46	195	21.23	10.19 - 9.17	2.08	2.31
6/94	195/1	14.54	425	14.54	4.68 - 4.08	3.106	3.56
4/95	2125/5	213.5	377	42.7	14.79 - 13.95	2.887	3.06
4/96	377/1	35.5	187	35.5	12.06 - 11.06	2. 94	3.209
2/97	187/1	13.88		13.88	4.48 - 3.88	3.098	3.577

1- Average Load

All values of a subject in general cannot represent a problem so that only one value may summaries all of them. Consequently, the input data for the load curves are summarized as a Population Mean which may be taken as a mean value or in the field of electricity as the average load X in the form:

$$X = [\Sigma X_i] / N, (i=1,...,N) \quad (14-20)$$

The average value of a load curve is the same as the mean for the statistical studies but here this average is tailored in different ways such as the *Instantaneous Mean* as given in Tables 14 - 13 , 14 - 14 and 14 - 15 for the three different cases inside the same overall readings of the load curves in Port Said City (Egypt).

Table 14 - 13: Daily average load for the 1st week of August 1999 (A)

Day	1	2	3	4	5	6	7
Average	1035	1215	1090.8	1131.6	1242.5	1066.6	900

Table 14 - 14: Daily average load for September 1999

Day	1	2	3	4	5	6	7
Average	1035	1039.1	1079.1	952.1	976.6	1213.3	714.1
Day	8	9	10	11	12	13	14
Average	1160.4	1045	855	904.1	1055.8	1192.5	1039.1
Day	15	16	17	18	19	20	21
Average	1025.8	755.8	942.1	1047.5	1270.8	1251.2	975
Day	22	23	24	25	26	27	28
Average	1227.5	1245	1093.3	1210.8	1143.3	1175.8	1133.3

Whatever, the daily average load can be computed for all instantaneous values as a statistical base of mathematics as listed in Table 14 - 13 for the first seven days of August inside the analyzed data. It is remarked some difference between results in above Tables and the next due to the automatic change in the consumed load.

The calculations for the other cases are given in Table 14 - 14 for September with the above remarks in deduced daily average loads. However, Table 14 - 15

lists the random collections of readings to prove that the value of mean load cannot express the actual view for the collections of data. This means that one or more factors may be needed. Since the single average value is absent, another one factor or more will be required to complete the view about measurements.

Table 14 - 15: Daily average load for some cases (units in A)

Case	Concept	Daily Average load	N
Days 1 , 20 , 23 /9	Random	1126.6	72
Days 1 , 7 ,25 /8		1124.7	72
Days 3 , 17 , 26 /8		1063.03	72
Sept.	Sundays	981.98	12 0

2- Dispersion Factors

This parameter expresses the shape of dispersion of the data around the mean value and it gives correctly their distribution along the studied period. So, another important factor besides the mean value must be accounted as the variance (S^2), which gives the known important parameter as the standard deviation (S) according to the formula:

$$S = \sqrt{\sum [X_i - X]^2 / N} , (i=1,...,N) \quad (14 - 21)$$

This standard deviation (S) for the population measurements will be expressed for the sampling method on (n) samples as (σ) in the form:

$$\sigma = \sqrt{\Sigma [X_i - \mu]^2 /(n-1)}, (i=1,\ldots,n) \quad (14 - 22)$$

Table 14 - 18 : The margin of different cases

Case	Class						
	1	2	3	4	5	6	7
(a)	21 - 220	221- 420	421 - 620	621 - 820	821 - 1020	1021 - 1220	1221 - 1420
(b) & (c)	0 - 299	300- 599	600 - 899	900 - 1199	1120 – 1499	-	-

It is seen that its value is approached from the normal distribution for the case (b) while it is more far for case (a). But the case (c) gives an abnormal condition for the shape of load curves in general where its value is positive. This leads to the great importance of such investigation (Fig. 14 - 6) so that the base of statistics may be essential for load curves presentation at all.

4- The Weight Loads Mean

The effect of peak on the load curve appears to be the most important item for Engineers and so, the statistical study for either peak or light loads may be applied according to:

$$X_W = [\Sigma \, Xi \, Wi \,] \; / \; \Sigma \, Wi \qquad (14 - 28)$$

The calculated values are drawn in Fig. 14 - 7 to prove that the peak is a heavy point in the design of a network with the load curve base.

5- CORRELATION FACTOR FOR LOAD CURVES

Whatever, the load varied not only by time but also with the place because the end users are continuously increased day by day, and consequently, the load may be changed. The given above statistical data for the Sundays may illustrate that performance so that the skew factor is approached to be a normal distribution. This means that the characteristics of a certain day are stable while the general

form of data distribution where it is formulated as:

$$\text{Group Mode} = Lmd + C\, Da/[Db + D\, a] \quad (14 - 25)$$

The standard deviation in this case is deduced according to the mathematical formula:

$$S = \sqrt{\Sigma[f\, M^2 - n\, X^2]/(n-1)} \quad (14 - 26)$$

Table 14 - 17: The calculated factors for the specified cases

Case	(a)	(b)	(c)
Condition	The first week of August	Sundays (September and August)	Individual month of September
Readings n	168	216	696
Average	1102.64	1072.83	1072.77
Mode	679.05	613.95	605.96
Median	1583.5	1952.3	645.33
Standard deviation	224.7	922.95	346
Skew ness Factor (P)	- 6.42	- 1.569	3.706

Consequently, the cumulative frequency can be accounted for the different cases of readings (Table 14 - 17) where their classes are determined in Table 14 - 18. These cases are denoted for the following Tables and Figures. The shown factor of skew is required to understand the shape of data along the distribution axes and it is defined by:

$$P = 3\,[\text{mean} - \text{median}] / S \quad (14 - 27)$$

performance is widely changing. The statistical study leads to a new correlation due to the unused energy in the network in spite of the company reserve it for them. So, the unused energy must be shared with customers in the process of accounting.

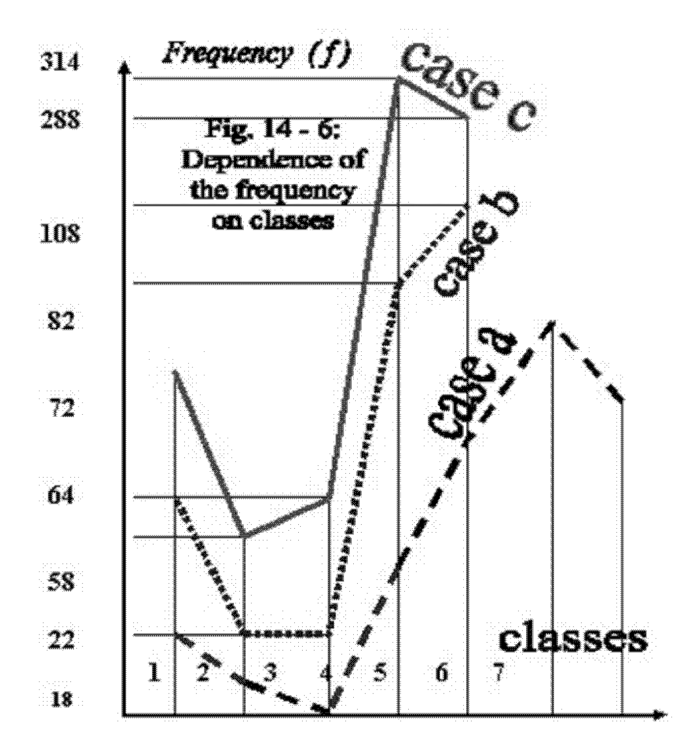


Fig. 14 - 6: Dependence of the frequency on classes

This correlation factor to load curve (Fig. 14 - 8) may be proposed to each or all consumers of the network as a function of the average load in the form:

$$\beta = (\Sigma X / E_t) \qquad (14-29)$$

Thus, the allowable energy to be generated will be included through the energy too inside the term of running cost of equation (14 - 13) while its installed value is computed with the capital cost. This can balance the process of costing for the energy consumption.

Thus, the proposed correlation factor for the accounting process will be suitable to cover any deviation in the readings in the process of energy costing in Egypt even if it is a multi month measuring. This correlation does not touch the tariff base. It can be recommended for application in the software concerning this item. Another correlation factor is needed on the statistical bases to cover the variation performance of the load curves.

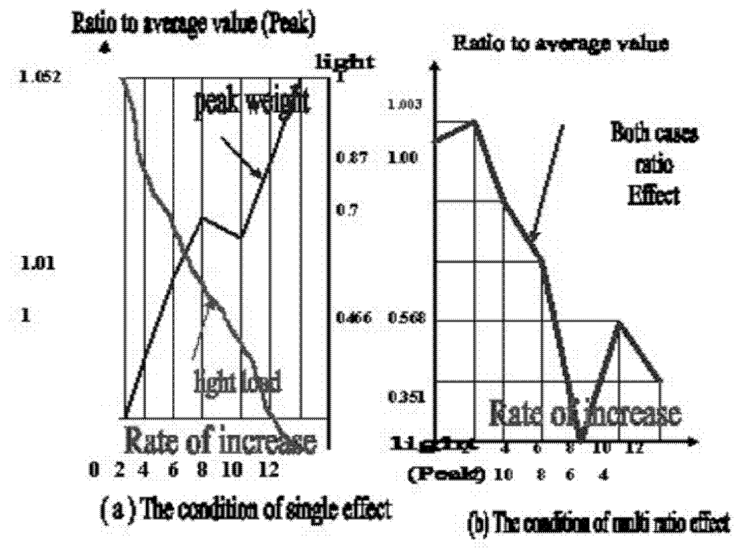


Fig. 14 - 7: The effect of weight of the peak and light load

The evaluated dispersion factor (standard deviation) for the studied data is given data in Table 14 - 16 for the load curves in September 1999.

Table 14 - 16: Standard deviations of readings

Case	Time	Average	N	S	σ	σ /S
1-10 September	Midnight	1236	10	31.61	35.12	1.11
1-7 August	Peak	1282.85	7	36.46	42.53	1.16
1-7 August	Light load	975.14	7	191.34	223.23	1.16
1/8/99	24 h	1035	24	64.35	67.14	1.04

The results show that the case of given data has a different value for the sampling process as a ratio (σ/ S) in the last column of the Table. This proves that more readings for the sample will be necessary to give accurate results.

3- Grouped Data

On the other hand, data may be scattered in a wide range and then the system of grouping will be the best concept for the evaluation process. This principle appears when the computation of Weekly Mean, as a *Grouped Mean* (X_g), which formulated as:

$$X_g = [\Sigma f \ M] / n = [\Sigma f \ M] / \Sigma f \quad (14-23)$$

This type of computations may be needed, too, for the determination of annual average load or even the monthly value. ......also, a median will be necessary for the results in the form:

$$\text{Median} = L_{md} + C \, [n/2 - F] \, / \, f_{md} \quad (14-24)$$

The group mode as one of the most important parameter for the grouped data would be necessary in order to determine the general

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